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October 20–21, 1986 Santa Clara
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These proceedings are a compilation of the papers presented at two symposia in October, 1986. The proceedings have a companion volume, Guide to Solvent Waste Reduction Alternatives, a study of source reduction, recycling, and treatment technologies published in 1986. These proceedings and the Guide provide practical tools to assist industry in: complying with applicable regulations; developing and implementing an overall solvent waste minimization strategy, including conducting waste audits; identifying cost-effective on-site/off-site solvent waste reduction alternatives; minimizing liabilities; and understanding present and planned government solvent waste program objectives.

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SOLVENT WASTE REDUCTION
ALTERNATIVES SYMPOSIA

CONFERENCE PROCEEDINGS

Sponsored by:

California Department of Health Services

October 20-21, 1986 Santa Clara
October 23-24, 1986 Los Angeles

Produced by:

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PREFACE

The California Department of Health Services is pleased to present these Symposia Proceedings on Solvent Waste Reduction Alternatives. These Proceedings are a compilation of the papers presented at two symposia sponsored by the Department of Health Services in October 1986. The Proceedings have a companion volume, Guide to Solvent Waste Reduction Alternatives, a study of source reduction, recycling, and treatment technologies published in 1986.

The Symposia, its Proceedings, and the Guide have been produced by ICF Consulting Associates, Incorporated under contract with the California Department of Health Services.

Under the 1984 Amendments to the Resource Conservation and Recovery Act, the Environmental Protection Agency is scheduled to implement new regulations restricting use of land disposal for solvent wastes. Recent and proposed state environmental regulations contain additional restrictions.

Responding to the changing regulatory environment will be a challenge for firms which generate or manage solvent wastes. These Proceedings and the Guide provide practical tools to assist industry in:

- Complying with applicable regulations;
- Developing and implementing an overall solvent waste minimization strategy, including conducting waste audits;
- Identifying cost-effective on-site/off-site solvent waste reduction alternatives;
- Minimizing liabilities; and
- Understanding present and planned government solvent waste program objectives.

SYMPOSIUM AGENDA

DAY ONE

Registration (7:30 - 12:00)

Opening Session (8:30 - 8:50)
David Leu, California Department of Health Services

Regulatory Ramifications (8:50 - 10:50)

- Santa Clara: Federal Perspective, Jeffrey Zelikson, U.S.EPA, Region IX
  Los Angeles: EPA's Land Disposal Restriction Program, Steve Weil, U.S.EPA
- State Regulatory Overview, Jan Radimsky, CDHS
- Santa Clara: Local Air Pollution Control, Jim Karas, BAAQMD
  Los Angeles: The District's Approach to Controlling Solvent Use and Disposal, Jo Anne Aplet, SCAQMD

  Coffee Break (10:05 - 10:25)
- Regulatory Incentives for Alternatives to Land Disposal, Patrick Dennis, Attorney-at-Law

Legal and Policy Issues (10:50 - 11:40)

- Source Reduction: Legal Issues, Robert Wyman, Attorney-at-Law
- Local Government Approaches to Waste Reduction, Donald Koepp, Ventura County Health Department

Luncheon with Keynote Address (11:40 - 1:20)

Alex R. Cunningham, Chief Deputy Director, Toxic Substances Control Division, California Department of Health Services.

Alternative Technologies: Integrated Approaches (1:20 - 5:00)

- Waste Minimization Audits, Stephen Kahane, ICF
- Waste Reduction at the Source: Incentives and Initiatives, Warren R. Muir, INFORM
- Santa Clara: Solvent Waste Reduction: Case Studies, Dave Brooks, Hewlett Packard; AEA
  Los Angeles: Liquid Waste Minimization at IBM San Jose, Ray Kerby, IBM; AEA

  Coffee Break (2:35 - 2:55)
- Waste Minimization and Alternative Technology, Edward L. Meyer, Aerojet General Corp.
- Waste Reduction Strategies in the Semiconductor Industry, Steven Pedersen, Semiconductor Industry Assoc.
- Solvent Recovery: An Industry Approach, Walter J. Mundy, Northrop Corp.

  Panel Discussion (4:10 - 5:00)

DAY TWO

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Alternative Technologies: Source Reduction
(8:30 - 9:45)

- Guide to Solvent Waste Reduction Alternatives: Source Reduction Practices, Carl Fromm, Jacobs Engineering Group
- Solvent Air Emissions Control, Donald R. Lee, Consultant
- VOC Emission Control by Means of Activated Carbon Adsorption, Larry J. Durr, D.C.I. Corp.

Coffee Break (9:45 - 10:05)

Alternative Technologies: Recycling
(10:05 - 11:45)

- Guide to Solvent Waste Reduction Alternatives: Recycling Practices, Barry Garelick, Versar Inc.
- On-site Solvent Recovery, Richard Sklar, Recyclene Products, Inc.
- Small Quanity Generators: What are the Options?, Paul DeVries, Roehl Disposal
- Santa Clara: Recycling and Incineration of Hazardous Waste Solvents: Economic and Policy Aspects, Seymour Schwartz, U.C. Davis
  Los Angeles: Recycling as a Means of Waste Minimization, Kenneth O'Morrow, OSCO

Luncheon (11:45 - 1:15)

Alternative Technologies: Treatment
(1:15 - 2:55)

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  Los Angeles: Pretreatment of Solvent-Contaminated Wastewater for Sewer Disposal, Philip Lo, L.A. County Sanitation Districts
- Burning Industrial Hazardous Waste Solvents in a California Cement Kiln, Michael Zimmer, Systech
- UV - Oxidation Systems for Controlling Chlorinated Solvents and Other Solvents in Water and Air, Jack Zeff, Ultrox International
- Utilizing Air Stripping Technology for Effluent and Pretreatment of Solvent Waste, Gary Carlton, McLaren Environmental Engineering

Coffee Break (2:55 - 3:15)

Solvent Waste: The Public Interest
(3:15 - 4:05)

- Toxicological Profile of Solvents - Workers' Health and Safety, Harry Skalsky, Woodward-Clyde
- Santa Clara: Reducing the Dilemma of Solvent Waste, David Roe, Environmental Defense Fund
  Los Angeles: Chlorinated Solvents: The Regulatory Dilemma, Katy Wolf, Rand

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* - Paper not submitted
** - Guide to Solvent Waste Reduction Alternatives

THE SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT'S APPROACH TO CONTROLLING SOLVENT USE AND DISPOSAL

Presented by Jo Anne Aplet, Director of Planning
South Coast Air Quality Management District

At The Technical Symposium:
Solvent Waste Reduction Alternatives

October 23, 1986
Los Angeles, California

THE SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT'S APPROACH TO CONTROLLING SOLVENT USE AND DISPOSAL

INTRODUCTION

Good morning. My name is Jo Anne Aplet. I am the Director of Planning for the South Coast Air Quality Management District. As many of you know, the District is responsible for air pollution control from stationary sources, including air emissions from solvents, for the area comprised of Los Angeles, Orange, and Riverside Counties, and the urbanized region of San Bernardino County.

I am pleased to be here this morning to discuss our current and future efforts to reduce emissions from solvent use and disposal. We are concerned about solvent use and disposal practices because solvent vapors are a major contributor to the formation of photochemical smog and represent a potentially significant source of toxic air contaminants.

At present, solvent vapors represent the largest stationary source of photochemically reactive organic compounds in this region. Their role in ozone formation is only second to that of the over five and one-half million automobiles. Because of this region's unique meteorology, topography, and demographics, it is particularly susceptible to the formation of ozone, the principal component of photochemical smog. We do not anticipate meeting the federal and California ambient ozone standard until beyond the year 2000, if ever. Clearly, efforts to further reduce photochemically reactive emissions from the use and disposal of solvents must be an integral component of the Basin's ozone control strategy.

In addition to their role in the formation of ozone, many solvents may also pose direct health risks due to their toxic nature. Several of the most commonly used solvents have already been placed by the Environmental Protection Agency and California Air Resources Board on their lists of potentially toxic air contaminants. These solvents include perchloroethylene, trichloroethylene, methyl chloroform, methylene chloride, and xylene. Each listed substance will be analyzed to fully assess the public health risk. If health risks are identified, control methods will be required to minimize the risk.

HISTORY AND PRESENT STATUS OF DISTRICT REGULATION OF SOLVENT USE AND DISPOSAL

Historically solvent usage has been controlled as a source of photochemically reactive compounds. The first air pollution control rule to regulate emissions from solvents was adopted by Los Angeles County in 1966. This rule, now referred to as Rule 442, sets specific emission limits for a formulation based on its relative photochemical reactivity. The effect of this requirement has been to essentially eliminate the use of many different types of solvents.

In order to further reduce emissions of solvent vapors, the District, since 1979, has adopted rules for specific industrial and commercial processes. Today the District's regulatory program covers almost every aspect of industrial and commercial solvent use. Table 1 summarizes the extent of our current regulatory program.

As can be seen in Table 1, our efforts are generally aimed at three major industrial and commercial uses of solvents: surface coating application and the associated use of solvents for thinning and clean-up, plastic and metal parts degreasing, and fabric cleaning. The other major source of solvent emissions which air pollution regulatory agencies are only beginning to address is household products. The contribution of ROG emissions from each type of solvent use is shown in Figure 2.

I will next outline for you the District's regulatory approach to reduce emissions from these three uses of solvents and summarize some of the methods used to comply with our requirements. Many of these methods serve the dual purpose of reducing air emissions and reducing and/or eliminating the generation of solvent wastes.

DISTRICT CONTROL APPROACHES AND COMPLIANCE METHODS

Coatings and Coating Application

Application of coatings represents the largest category of air emissions from solvent use in the Basin. The District's basic control approach is a technology forcing one which relys on increasingly stringent volatile organic compound limits. This control approach has resulted in lower solvent formulations and improved application and control technologies. For certain types of coatings, however, a slower than expected advancement in technology has occurred. This has prompted the District to establish demonstration programs in lieu of implementing more stringent limits. These programs required major coating users to conduct tests of coatings with lower contents of volatile organic compounds. The results of these tests are currently being analyzed by District staff.

A number of methods are currently employed to reduce solvent use and emissions from coating operations. They include: (1) using lower solvent coating formulations such as higher-solid, waterborne, powder, radiation curable, and exempt solvent based; (2) process modifications such as changing application techniques and the design of the product; and (3) the installation of add-on air pollution control devices such as afterburners, carbon adsorption, and scrubbing devices.

I won't go into the relative advantages and disadvantages of each of these techniques, since this is often a function of the specific product being coated and because they are discussed very thoroughly in your manual.

Parts Degreasing

The second major use of solvent that I will address is the cleaning of plastic and metal parts. This process is generally carried out in degreasers which are sold and serviced as packaged units. These degreasers are located throughout the region. They are used in neighborhood businesses such as auto repair shops and in large industrial manufacturing facilities such as aerospace plants. Individually the smaller degreasers do not contribute a significant amount of emissions, but in combination with larger units, they represent a major source of reactive organic gases.

The extreme variation in design and size of these degreaser units makes an emissions limit approach difficult. Therefore, the District has opted for an approach based on equipment design, operation and maintenance specifications.

Through implementation of our requirements, we have found a number of methods being employed to curtail evaporative solvent vapors. These methods reduce overall solvent usage and waste. For example, we have found companies: switching to alternative cleaning and paint stripping methods; switching to aqueous or other non-solvent cleaning agents; switching to less reactive solvents; increasing the recyclability of solvent use in the plant's operation by standardizing solvent use throughout the plant and maintaining solvent quality; altering the design of the degreaser to prevent air losses, good operating and maintenance practices of the degreaser; using add-on air pollution control devices; and/or eliminating the need to clean parts through process modifications. Again the relative merits of each of these methods are covered in your manual.

Fabric Cleaning

Fabric cleaning is also a major source of solvent vapors in the Basin. Dry cleaners are also located throughout the Basin and include the neighborhood dry cleaning shops operating on an independent basis, the franchise dry cleaning shops, the specialty cleaners which handle leather and fine goods, and the large commercial cleaners which service hotels and other businesses.

The District's control approach for this source is to require, for all dry cleaners, good housekeeping and maintenance practices as well as special handling practices for waste disposal. Most dry cleaners are also required to install and properly maintain an air pollution control device which has a control efficiency of 90% or greater. The two most common types of control equipment employed are carbon adsorbers and refrigeration condensation units.

Emission controls on dry cleaners have historically been required as part of the region's ozone control strategy. However, now the emphasis is shifting to controlling dry cleaners as a source of toxic air contaminants. Approximately 90% of all dry cleaners utilize perchloroethylene as their cleaning solvent. This compound is currently under investigation by the District, the California Air Resources Board, and EPA as a potential toxic air contaminant.

FUTURE CONTROL EFFORTS

While implementation of our regulatory program for these three categories of solvent use has significantly reduced air emissions, we need to continue to seek and develop further control approaches. Additional controls are needed to maximize progress toward the federal and California ozone standards.

I would like to briefly describe two planning efforts currently underway which will lead to further reductions of air emissions from solvent use. These are EPA Region IX's Reasonable Extra Efforts Program, commonly referred to as REEP, and the second revision to the region's Air Quality Management Plan which is underway.

EPA Reasonable Extra Efforts Program

The Federal Clean Air Act, as amended in 1977, required each area in the nation to attain federal ambient ozone standards by 1982. This act provided an extension to 1987 for areas needing additional time to meet the ozone standards. The Clean Air Act has not been revised and the 1987 deadline still stands. In addition to the South Coast Air Basin, many other urban areas of the country now find that they cannot comply with the 1987 deadline. At the prospect of widespread noncompliance, and in the absence of a revision to the Clean Air Act, EPA is now seeking a way for post '87 attainment areas to comply with the intent of the federal statutes.

Region IX EPA, which has responsibility for California, Arizona, and Nevada, has developed what it calls the "Reasonable Extra Efforts Program" or REEP. Under this program, EPA has identified measures or parts of measures which have been adopted elsewhere in the country, and advised nonattainment areas that they must either adopt rules equivalent to the strictest in place anywhere in the country or provide reasons acceptable to EPA why they cannot. Meanwhile, national EPA offices are developing a "Sustained Progress Program" (SPP) also directed at maintaining progress in post '87 areas while avoiding the need to impose sanctions. Details of the Sustained Progress Program have not been developed.

For the South Coast Air Basin, the REEP process is underway. Thus far, EPA has identified sixteen source categories, where further controls are believed possible. Many of these are solvent use categories. It is anticipated that this program will help to identify further means of reducing solvent use and waste.

Air Quality Management Plan Revision

The AQMP is a comprehensive policy statement which delineates air quality standards, pollution reduction strategies and implementation responsibilities for improving air quality in the Basin. Currently, an AQMP update is underway and scheduled for completion in the latter part of 1987 or early 1988. The emphasis in this revision will be on ozone control approaches. As part of this effort, short- and long-range control measures are being developed for further reducing solvent use.

For this next Revision, we are investigating not only further control of the traditionally large solvent users, but also small users of solvent, most of which are also small quantity generators of solvent wastes. Some of these small users include auto-repair and repaint shops, small dry cleaning establishments, electronics manufacturers, photofinishing labs, and other sources listed in Table 4-2 of the symposium guide. We are investigating not only the use of solvent, but disposal practices; a growing source of solvent vapors are landfills and sewage and groundwater treatment facilities. In addition, the District, along with the California Air Resources Board, is investigating potential control approaches for household solvent-borne products such as household cleansers, insecticides, automotive, and personal care products.

A number of issues are emerging from our efforts to develop further controls. These issues include the fact that smaller and smaller sources will need to be controlled. This will require greater use of outreach programs and technical seminars. Also there is the issue of tradeoffs between regulating criteria pollutants and increasing potential toxic exposure. As noted earlier, solvent emissions are coming under investigation by the District, the ARB, and EPA as potential toxic air contaminants. The air toxics problem is only just beginning to be defined. Toward this end, the District is conducting a study funded by EPA to develop a profile of population exposure to twenty air toxic contaminants, several of which are organic solvent gases. Finally, these issues may necessitate the restructuring of our current regulatory approach, using economic incentives and disincentives to supplement our technology-forcing requirements, seasonal controls, and/or controls conditioned upon the time and place of the emissions release.

Currently we are preparing a working paper which identifies additional stationary source measures for the 1987 AQMP. This paper is the fourth in a series of working papers which are to form the foundation of the 1987 AQMP Revision. This paper is designed to set forth proposals for public discussion of feasibility, cost impacts, and other issues of concern, as well as to solicit additional suggestions for potential control approaches. We are tentatively planning to release this paper late this year.

SUMMARY

In summary, solvent use and disposal is a significant source of air pollution. Vapors from solvents are a major contributor to the formation of photochemical smog as well as being a source of potentially toxic air contaminants. Because of these effects, the District has implemented an extensive regulatory program and efforts are underway to identify new measures to further reduce the release of solvent vapors. Prominent among considerations regarding new controls is the mandate of solvent use and waste reduction techniques. Implementation of these techniques in combination with others will result in significant progress toward regional air quality and hazardous waste goals.

Thank you for this opportunity to allow us to present our current and future control efforts.

TABLE I
THE SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT
CURRENT REGULATORY PROGRAM FOR SOLVENT USE

Name	Number	Description
Usage of Solvents	442	Restricts the discharge of organic materials into the atmosphere from equipment in which solvents are used.
Labeling of Solvents	443	Requires coatings and solvents to be labeled to indicate its photochemically reactivity.
Spray Coating Operations	481	Establishes requirements for all spray painting and spray booths.
Petroleum Solvent Dry Cleaners	1102	Establishes operating and control requirements for petroleum solvent dry cleaners.
Perchloroethylene Dry Cleaning Systems	1102.1	Establishes operating and control requirements for dry cleaners which use perchloroethylene as their cleaning solvent.
Wood Flat Stock Coating Lines	1104	Establishes VOC standards for coatings applied to wood panels and other wood products.
Manufactured metal Parts and Products Coating	1107	Establishes applications requirements and VOC standards for coatings applied to metal parts and products.
Cutback Asphalt	1108	Restricts the manufacture and use of cutback asphalt containing more than a certain level of organic compounds.
Architectural Coatings	1113	Establishes VOC standards for architectural and specialty architectural coatings.

TABLE I
THE SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT CURRENT REGULATORY PROGRAM FOR SOLVENT USE
(continued)

Name	Number	Description
Automobile Assembly Line Coating Operations	1115	Establishes VOC standards for top-coats and primers applied to automobiles.
Solvent Cleaners	1122	Establishes operating maintenance and control requirements for the use of solvent degreasers.
Aerospace Assembly and Component Operation	1124	Establishes specific VOC standards for coating operations in the aerospace industry.
Can and Coil Coating Operations	1125	Establishes standards for coatings applied to cans and coils.
Magnet Wire Coating	1126	Establishes standards for magnet wire coatings.
Paper and Fabric Coating Operations	1128	Establishes standards for coatings applied to paper and fabric.
Graphic Arts	1130	Establishes operational requirements for the graphic arts industry as well as VOC standards for graphic arts materials.
Wood Furniture and Cabinet Coatings	1136	Establishes application requirements and VOC standards for coatings applied to wood furniture.
Control of ROG from Resin Manufacturing	1141	Establishes operating requirements for manufacturing of resins.
Coatings and Ink Manufacturing	1141.1	Establishes operating requirements for coatings and ink manufacturing.

FIGURE I

CONTRIBUTION OF SOLVENT USE
TO THE TOTAL ROG EMISSIONS INVENTORY
IN THE SOUTH COAST AIR BASIN
(1008 TONS/AVG ANNUAL DAY)

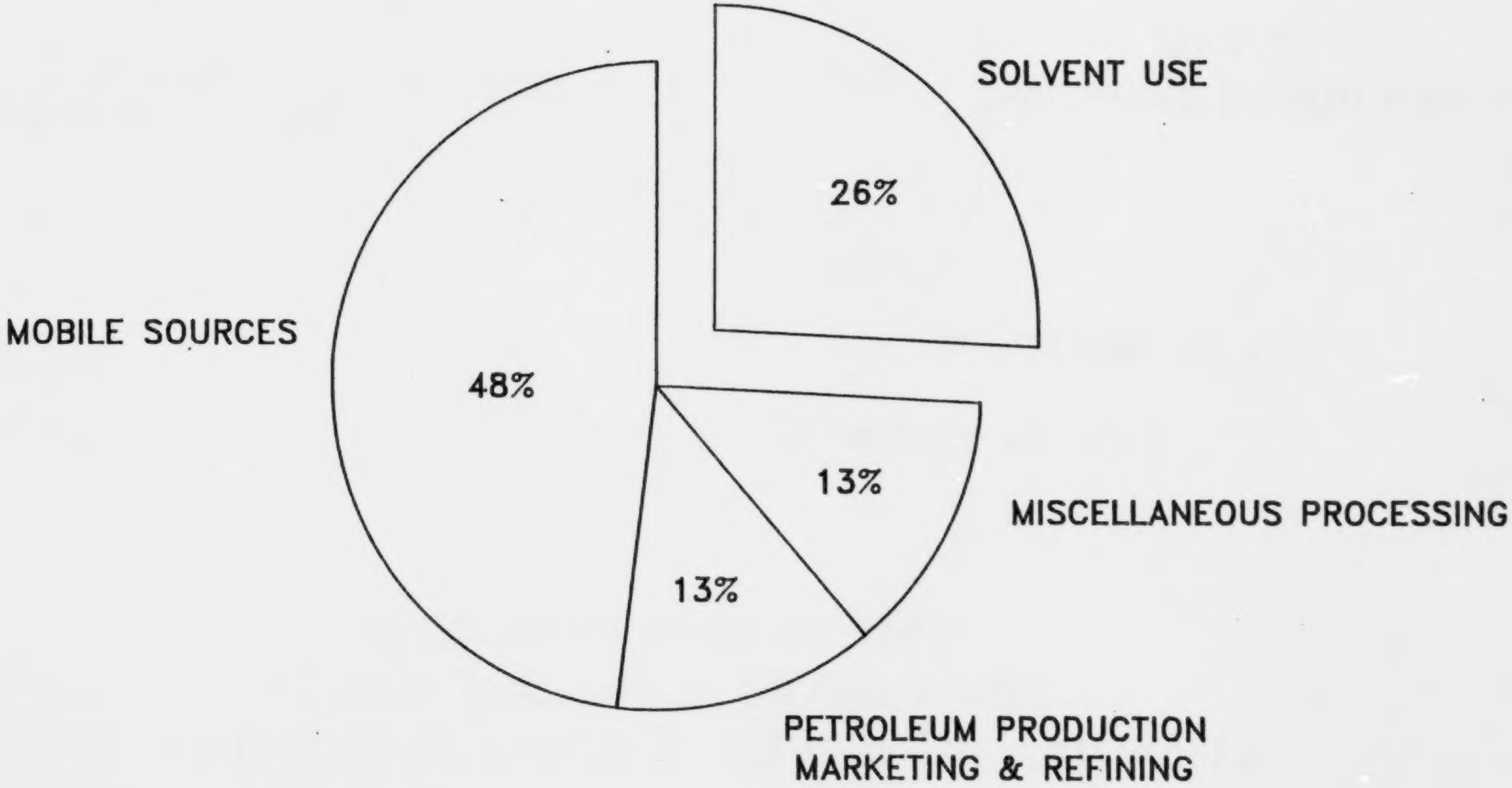
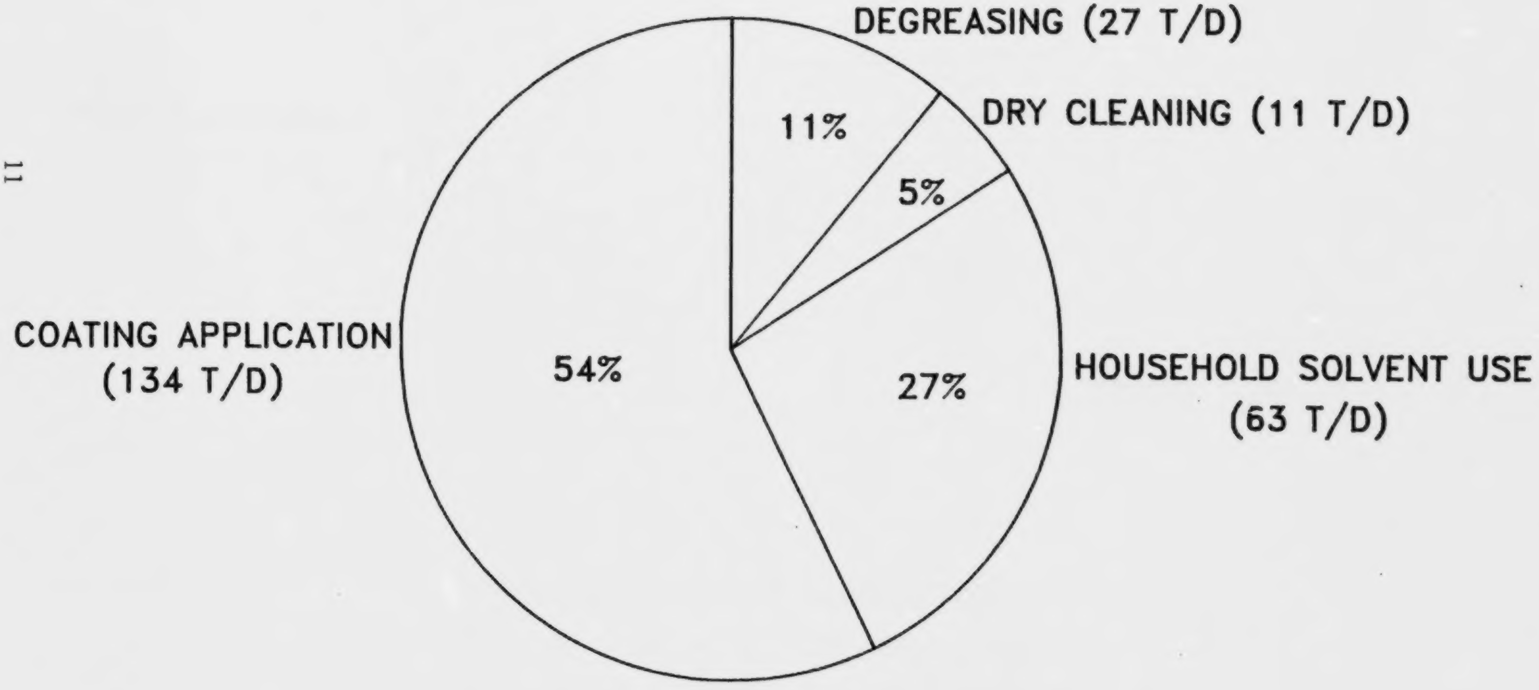


FIGURE II

CONTRIBUTION OF DIFFERENT SOLVENT USE CATEGORIES
TO TOTAL EMISSIONS OF SOLVENT VAPORS
IN THE SOUTH COAST AIR BASIN



SOLVENT WASTE REDUCTION: CASE STUDIES

by
David W. Brooks
Environmental Projects Engineer
Corporate Environmental Health & Safety
Hewlett Packard
Palo Alto, California

SOLVENT WASTE REDUCTION: CASE STUDIES

I. INTRODUCTION
  A. HP's MANUFACTURING PROCESSES
  B. HP's ENVIRONMENTAL ORGANIZATION
  C. HAZARDOUS WASTE GENERATION DATA

II. WASTE MANAGEMENT PROGRAM
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    1. EQUIPMENT EVALUATION
    2. CASE STUDY, DEGREASER AND STILL - HP BOISE
  C. ON-SITE REUSE
    1. CASE STUDY, CLEAN ROOM AND PAINT SHOP - HP ANDOVER
  D. PROCESS CHANGE
    1. CASE STUDY, PC PHOTORESIST STRIPPER - HP COLO. SPRINGS
    2. CASE STUDY, IC PHOTORESIST APPLICATOR - HP SANTA CLARA
  E. PROCEDURE CHANGE
    1. CASE STUDY, DEGREASER SEGRATION - HP WALTHAM

UTILIZING AIR STRIPPING TECHNOLOGY FOR PRETREATMENT OF SOLVENT WASTE

by

Gary M. Carlton
McLaren Environmental Engineering
Rancho Cordova, CA

There are several treatment technologies for the treatment, separation, or removal of solvents from aqueous wastestreams. Solvents are a significant component of the aqueous waste streams from several industrial classifications. The first part of this work focuses on four of these industries, and will summarize the solvent concentrations that are expected in the liquid waste stream from each industry. The second part of this work will outline and briefly describe applicable methods for treatment of solvents in the aqueous stream, and will present performance and design criteria, and a cost analysis for the method of air stripping.

SPECIFIC INDUSTRIAL WASTE STREAMS

Several industrial classifications currently utilize, as part of their manufacturing operations, halogenated solvents. These industries, therefore, generate waste streams containing various concentrations of these solvents. The focus of this work will be on four of these industries.

- Semiconductor manufacturing
- Metal finishing
- Paint manufacturing
- Aerospace industry

Semiconductor Manufacturing

Semiconductors are solid state electrical devices which perform a variety of functions. These functions include information processing and display, power handling, and the conversion between light energy and electrical energy. Semiconductors are used throughout the electronics industry. The major semiconductor products are:

- Silicone-based integrated circuits which include dipolar MOS (Metal on Silicon), and analog devices;

- Gallium arsenide and gallium phosphide wafers for the production of light emitting diodes (LED's);

- Silicon and germanium for diode and transistor production; and

- Glass wafer devices such as for liquid crystal display (LCD) production.

All these processes use organic solvents in their rinsing and drying operations. As an example, consider liquid crystal display production. The process begins with flat glass cut into 4-inch squares. These plates are cleaned by sequential immersions in ammonium hydroxide, a mild alkaline solution, and deionized water. The plates are then spun dry and sent for further processing.

This further processing includes a series of coatings and rinses with both deionized water and organic solvents. An oxide layer is then deposited which is subsequently rinsed and dried. The plates are then baked and cut.

The glass is then cleaned in an alkaline solution and rinsed in deionized water. After inspection, a layer of silicon dioxide is evaporated onto the surface to provide alignment for the crystal. Two mirror-image pieces of glass are then aligned and heated in a furnace. The space between the plates is evacuated and injected with a liquid crystal compound. The glass is then sealed with an epoxy, vapor degreased with a solvent, shaped on a diamond wheel, inspected, and sent to assembly.

The Office of Research and Development of EPA surveyed the raw wastewater at seven different plants' scrubbers in 1981. Scrubber wastewater data were chosen for their consistency. Table 1 summarizes their findings.

Table 1
SUMMARY OF HALOGENATED SOLVENT CONCENTRATIONS IN SEMICONDUCTOR INDUSTRY RAW WASTEWATER[1]

COMPOUND (ug/L)	NUMBER OF SAMPLES/ NUMBER OF DETECTIONS	RANGE OF DETECTIONS	MEAN OF DETECTIONS	MEDIAN OF DETECTIONS
Carbon tetrachloride	10/1	25		
1,2,4-Trichlorobenzene	10/1	36		
1,2-Dichloroethane	10/1	11		
1,1,1-Trichloroethane	10/4	25-73	40	31
1,1,2-Trichloroethane	10/1	<10		
Chloroform	10/6	<10-2,600	<440	10
2-Chlorophenol	10/4	<10-11	<10	10
1,2-Dichlorobenzene	10/4	<10-22	<14	12
1,4-Dichlorobenzene	10/3	<10-<10	<10	<10
1,2-trans-Dichloroethylene	10/1	13		

Table 1
SUMMARY OF HALOGENATED SOLVENT CONCENTRATIONS IN SEMICONDUCTOR INDUSTRY RAW WASTEWATER[1]
(Continued)

COMPOUND (ug/L)	NUMBER OF SAMPLES/ NUMBER OF DETECTIONS	RANGE OF DETECTIONS	MEAN OF DETECTIONS	MEDIAN OF DETECTIONS
2,4-Dichlorophenol	10/1	<10		
Methylene Chloride	10/6	<10-1,900	<330	<10
Trichlorofluoromethane	10/2	<10-16	<13	
Tetrachloroethylene	10/4	<10-74	<31	<10
Trichloroethylene	10/2	<10-80	<45	

Metal Finishing

The metal finishing industry is composed of several unit operations involving the machining, fabrication, and finishing of metal products. The operations performed usually begin with a raw stock in the form of rods, bars, sheets, castings, forgings, etc. and can progress to sophisticated surface finishing operations. The industry is diverse with wide variations in the age, size, number, and types of operation performed within its facilities.

The unit operations which utilize halogenated solvents in their processing include:

- **Cleaning** involves the removal of oil, grease, and dirt from the surface of the basis material.
- **Heat treating** is the modification of the physical properties of the workpiece through the application of controlled heating and cooling cycles.
- **Electrochemical machining** is the removal of a thin coating of metal. This is accomplished by pumping an electrolyte between the workpiece (the anode) and the tool (the cathode). Once a potential is applied, metal is rapidly removed from the surface of the workpiece.
- **Solvent degreasing** is the process of removing oils and grease from the workpiece through the use of solvents. Ultrasonic vibration may be applied to facilitate degreasing of complex shapes.

- **Paint stripping** is the process of removing an organic coating from a workpiece.

- **Painting** is the process of applying an organic coating to a workpiece. These coatings may be paint, varnish, lacquer, etc. and may be applied by spraying, dipping, brushing, etc.

- **Electrostatic painting or electropainting** are processes which apply a coating to a workpiece by making it either anodic or cathodic. Electrostatic painting is generally done by spraying while electropainting is generally done by dipping of the workpiece in an aqueous emulsion of the coating material.

The solvent-containing raw waste streams are generated by the dumping of spent solvents from degreasing equipment (including sumps, water traps, and stills). These streams are generally amenable to reclamation by distillation. In 1981, the EPA surveyed the raw wastewater streams from machine sumps and process tanks and has presented the following concentrations of halogenated compounds in raw wastewater:

TABLE 2
SUMMARY OF HALOGENATED SOLVENT CONCENTRATIONS IN
OILY, RAW WASTEWATER STREAMS IN THE METAL FINISHING INDUSTRY[1]

COMPOUND (ug/L)	NUMBER OF SAMPLES/ NUMBER OF DETECTIONS	RANGE OF DETECTIONS	MEAN OF DETECTIONS	MEDIAN OF DETECTIONS
Carbon tetrachloride	37/5	1-10,000	97	2,600
1,2-Dichloroethane	37/6	9-2,100	1,400	1,000
1,1,1-Trichloroethane	37/18	1-1,300,000	260	75,000
1,1-Dichloroethane	37/11	2-1,100	600	460
1,1,2-Trichloroethane	37/4	6-1,300	10	330
1,1,2,2-Tetrachloroethane	37/2	6-570		290
Chloroform	37/19	2-690	10	58
1,1-Dichloroethylene	37/12	2-10,000	200	1,500
1,2-trans-Dichloroethylene	43/9	8-1,750	88	510
Methylene chloride	37/29	5-7,600	92	600
Methyl chloride	37/4	1-4,700	9	1,200
Bromoform	37/1	10		
Dichlorobromomethane	37/2	1-10		5
Trichlorofluoromethane	37/2	260-290		280
Chlorodibromomethane	37/3	1-10	2	4
Tetrachloroethylene	37/18	1-110,000	10	8,900
Trichloroethylene	37/11	1-130,000	110	23,000

Paint Manufacturing

The paint manufacturing industry provides paint, varnish, and lacquer for trade sales or industrial applications. All paints and most lacquers contain pigments and extenders such as calcium carbonate, clays, and silicates. Other common allied products produced by the paint industry include epoxy compounds, asphaltic coatings, adhesives, sealants, paint removers, and stains.

There is little difference in the production processes used to produce either solvent-base or water-base paints. The major production difference is the carrying agent; solvent-base paints are dispersed in an oil mixture, while water-base paints are dispersed in water with a biodegradable surfactant as the dispersing agent. The cleanup procedure also differs for each production process. Because the water-base paints contain surfactants, formulating tanks can be easily cleaned with water. Tanks used to make solvent-base paint are generally cleaned with an organic solvent, but cleaning with a strong caustic solution is also common practice.

The principal raw materials used in paint manufacture, in terms of pounds consumed, are oils, resins, pigments, and solvents. Drying oils, such as linseed oil, are used at the film-forming binder in some solvent-base paints. Semidrying oils are used in the manufacture of water-base (latex) paints.

The paint industry is a large consumer of solvents, which are used as the volatile vehicles in coatings and certain specialty products. Mineral spirits, toluene, xylene, naphthalene, ketones, esters, alcohols, and glycols are the major solvents used. In addition, the industry consumes a wide variety of other additives and chemical specialties such as dryers, bactericides and fungicides, defoamers, dispersants, and thickeners.

All paints are generally made in batches. Batch size is an indicator of paint plant size. A small paint plant will produce batches of 100 to 500 gallons, while a large plant will manufacture batches up to 6,000 gallons. Because of the large number of color formulations generally produced, a continuous process is not feasible.

Since solvent-based paint production uses the predominant volumes of solvent in the industry, its process will be described.

The three major steps involved in the solvent-base paint manufacturing process are (1) mixing and grinding of raw materials, (2) tinting and thinning, and (3) filling operations.

At most plants, the mixing and grinding of raw materials for solvent-base paints are accomplished in one production step. For high-gloss paints, the pigments and a portion of the binder and vehicle are mixed into a paste of specified consistency. The paste is fed to a grinder or mill, which disperses the pigments by breaking down particle aggregates rather than reducing the particle size. For other paints, raw materials are mixed and dispersed in a mixer.

Following the mixing and grinding of raw materials, the paint is transferred to tinting and thinning tanks in which the remaining binder and liquid, as well as various additives and tinting colors, are incorporated. The paint is then analyzed, and the composition is adjusted as necessary to obtain the correct formulation for the type of paint being produced. The finished product is then transferred to a filling operation for filtering, packaging, and labeling.

Following the production of solvent-based paint, the sides of the preparation tank are rinsed with a solvent. This solvent is then recycled and no waste stream is discharged. The preparation tank of a water-based operation is, at times, rinsed with solvents. These waste streams are generally reclaimed, however, some are discharged to a treatment plant. The EPA presented the results of their survey of all wastewater streams in the paint industry in 1981. The results of that survey are shown in Table 3.

TABLE 3
SUMMARY OF HALOGENATED SOLVENT CONCENTRATIONS IN
RAW WASTEWATER STREAMS IN THE PAINT PRODUCTION INDUSTRY[1]

COMPOUND (ug/L)	NUMBER OF SAMPLES/ NUMBER OF DETECTIONS	AVERAGE OF DETECTED VALUES	MEDIAN OF DETECTED VALUES	MAXIMUM OF DETECTED VALUES
Carbon tetrachloride	27/8	3,800	14	30,000
Chloroform	27/14	200	110	900
Dichlorobromomethane	27/1	27		
1,1-Dichloroethane	27/1	BDL		
1,2-Dichloroethane	27/5	120	33	420
1,1-Dichloroethylene	27/5	140	23	620
1,2-trans-Dichloroethylene	27/2	140	140	260
1,2-Dichloropropane	27/3	330	12	970
Methylene Chloride	27/17	34,000	790	210,000
Tetrachloroethylene	27/17	600	230	4,900
1,1,1-Trichloroethane	27/15	150	82	930
1,1,2-Trichloroethane	27/5	570	BDL	2,800
Trichloroethlene	27/15	90	52	250

BDL - Below Detection Limit

Aerospace Industry

Industrial activities associated with the aerospace industry fall into two broad categories; solid rocket manufacturing and testing and liquid rocket manufacturing and testing.

Solid rocket manufacturing activities consist of propellant processing and rocket motor manufacturing.

Propellant processing includes fuel preparation, oxidizer preparation, and propellant mixing. Fuel preparation is carried out in temperature and humidity controlled buildings. Here the liquid and solid fuel ingredients are weighted and blended to form the fuel for the propellant. Closed vessels are used for storing, mixing, and blending the ingredients. In oxidizer preparation operations ammonium perchlorate, an oxidizing agent, is ground in humidity controlled buildings into the desired particle size for specific propellant formulations. Process equipment includes grinding mills, pulverizers, and product bins. Propellant mixing consists of adding and mixing oxidizer, prepared at the grind station, to fuel prepared at the fuel preparation station.

Solid rocket motor manufacturing can be described as four basic operational activities; inert parts fabrication, inert parts preparation, motor casting, and final assembly and shipment. Inert parts fabrication consists of steel chamber manufacture, filament winding of glass chambers, and nozzle fabrication and assembly. These operations use ordinary metal working equipment, such as lathes, rolling and welding tooling, heat-treatment furnaces, degreasing equipment, and filament-winding equipment.

Inert parts preparation normally includes chamber degreasing, sandblasting, installation of insulation, application of liner material, painting, and assembly of component parts. Processing equipment includes degreasers, sandblasting equipment, ovens, spray applicators of liner material, and paint booths.

Prior to casting propellant into the prepared chamber, the core and cast tooling is prepared and assembled into the rocket chamber. After the chamber is assembled with cast tooling, it is put into a vacuum bell. The mix bowl is brought from the mix station, positioned over the motors and connected to the motor for casting. The motor remains in the bell under vacuum until the propellant cures and hardens. After cure, the core is stripped from the motor and excess propellant is trimmed. The motor is then ready for final assembly.

Final assembly includes application of external insulation, installation of aft closure and nozzle, and final finishing in a facility equipped for this purpose. Painting and decal application concludes rocket motor processing. Process equipment consists of weight and center-of-gravity scales and paint booths.

Solid rocket propellant processing and rocket motor manufacturing utilize large quantities of solvents to ensure the cleanliness of casings and tooling.

Solid rocket motor testing consumes the solid propellant and generally destroys the usefulness of all inert parts. Therefore, testing is generally done only on development motors and on selected quality assurance motors during production. The finished motor is attached to the test stand and fired to test propellant and motor performance. Once a motor has been tested the inert components are sent to an inspection station. Solid rocket motor testing does not utilize solvents or result in the generation of aqueous waste.

Liquid rocket manufacturing involves parts fabrication and assembly. Metal parts fabrication consists of conventional metal machining, electrical discharge machining, welding, heat-treating, furnace brazing, photo etching, painting, and industrial cleaning. The plastics fabrication process consists of layup, winding on mandrels, hydro- or auto-claved curing, and bonding operations for production of combustion chamber liners and skirts. Assembly operations consist of the joining of fabricated and purchased parts into sub-assemblies and assemblies for dimensional and functional verification in the various laboratories and assembly areas. The use of solvents in liquid rocket manufacturing operations is comparable to that encountered with any metal-working operation.

Liquid rocket testing, unlike solid rocket testing, is designed to be a non-destructive process in which the rocket engine is fired for performance evaluation, modified as required, and retested until the desired results are achieved. Liquid rocket engines are usually mounted vertically on test stands and fired for testing purposes, then cleaned on the test stands using solvents. Cleaning procedures include use of hot solvents and water to flush all remaining fuel and oxidizer from the systems.

Representative composition and average annual generation of solid and liquid rocket manufacturing solvent-containing waste streams are presented in Tables 4 and 5.

TABLE 4

SOLID ROCKET MANUFACTURING SOLVENT-CONTAINING WASTE STREAMS

Waste Category	Primary Composition	Average Annual Generation (Gallons)
Miscellaneous Chemicals	98% H_2O; minor 1,1,1-TCA, Freon, TCE	440,000
Liner/submix/ premix	<25% solvent; includes 1,1,1-TCA, Methylene chloride, Toluene	10,000
Solvents	>90% pure solvent; includes 1,1,1-TCA, TCE, Toluene, Methyl Alcohol, Benzene, Methylene Chloride, Xylene, Methyl ethyl ketone	4,000
Solvent and Water	>60% H_2O; includes 1,1,1-TCA, TCE, Methylene Chloride, Toluene, Xylene, Benzene, Methyl ethyl ketone, Methyl Alcohol	1,500
Solvents and Liner	>50% solvent; includes Methylene Chloride, Methyl ethyl ketone, Methyl isobutyl ketone, 1,1,1-TCA, Toluene Diisocyanate	20,000

TABLE 5

LIQUID ROCKET MANUFACTURING SOLVENT-CONTAINING WASTE STREAMS

Waste Category	Primary Composition	Average Annual Generation (Gallons)
Bulk Liquids	99% H_2O; includes 1,1,1-TCA (0-105 ppm), Perchloroethylene (0-21 ppm), Freon 113 (0-14 ppm) Chloroform (0-2.5 ppm), Bromodichloromethane (0-0.5 ppm), (0-0.5 ppm), TCE (0-0.4 ppm)	1,220,000

TABLE 5

LIQUID ROCKET MANUFACTURING SOLVENT-CONTAINING WASTE STREAMS (Continued)

Waste Category	Primary Composition	Average Annual Generation (Gallons)
Aqueous Solutions	>50% H_2O; includes Perchloroethylene, TCE, Methyl ethyl ketone, Toluene	2,500
Liquid Chemicals	Freon 113, 1,1,1-TCA, Perchloroethylene, TCE, Toluene, Xylene, Methyl ethyl ketone, and other solvents	4,500

TREATMENT METHODS

There are several methods applicable to the treatment, separation, or removal of solvents from the waste streams typical to the industries described above. These treatment methods include:

- Distillation
- UV-Ozonation
- Air Stripping
- Carbon Adsorption

Distillation

Of these four methods, distillation is most applicable to concentrated wastes, where metals, water, or other solvents contaminate the single solvent or solvent mixture. The contaminants (metals or diluting water) can be removed, and the solvents can be separated and reclaimed, using one or a series of distillation column(s). For industrial uses in metal finishing shops or spray booths where relatively small quantities of many different solvents can be generated each day, a wide variety of small distillation units are available which can distill small quantities of waste in batch runs (ie. 5-25 gallons per batch). The metal contaminants collect in the bottom of the still for easy disposal.

Oxidation

The options for non-reclaimable solvents in aqueous waste form are limited. Discharge to the sewer system is not allowed until the aqueous wastes have been treated and solvents removed.

UV oxidation is applicable to treatment of highly concentrated organic wastes. UV-ozonation or photolysis is particularly applicable to wastes containing chemicals that are not volatile and therefore cannot be easily stripped from the waste stream, but that need to be removed before discharge of the liquid waste.

The process utilizes ultraviolet light and an oxygen source (such as hydrogen peroxide) to breakdown the organic compounds in the aqueous stream. Treatment can be accomplished in a columnar reactor with UV lamps in quartz tubes running through the center. Hydrogen peroxide is added to the liquid waste before the inlet to the column.

Carbon Adsorption

Carbon adsorption is a treatment method useful for removal of solvents from aqueous streams in cases where the solvent is easily adsorbed but not easily stripped or in cases where solvent concentrations must be reduced to very low concentrations (ie. less than detectable concentrations) before discharge of the aqueous stream.

Carbon adsorption is typically accomplished in steel tanks of variable size (200 to 20,000 pounds). The liquid waste stream inlet and outlet are at the top of the tank.

A disadvantage of carbon use is that when high concentrations of some solvents are adsorbed, the carbon adsorptive capacity is quickly exhausted. When "breakthrough" or carbon exhaustion occurs, the carbon must be replaced. Regular replacement of carbon can make carbon adsorption an uneconomical method for removal of solvents from waste streams.

Air Stripping

Finally, air stripping is a useful method for removing solvents from moderate to dilute aqueous streams. For large volumes of aqueous waste, air stripping towers are the most economical and effective solvent removal method. The remainder of this work will describe performance criteria, design criteria, cost assumptions, economic evaluation, and operation and maintenance costs for air stripping.

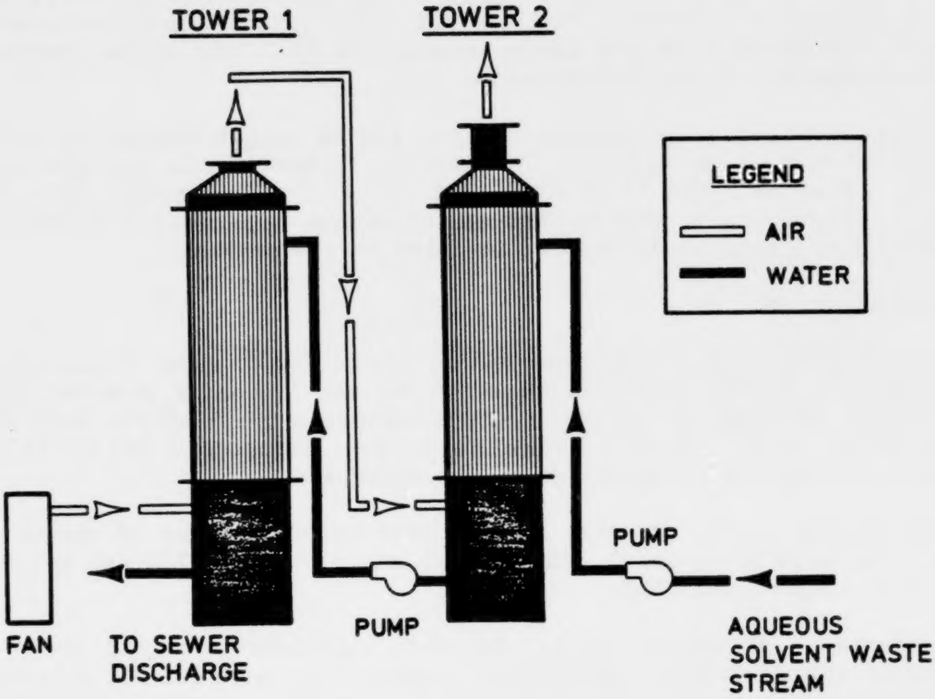
TOWER 1
TOWER 2
LEGEND
AIR
WATER
FAN
TO SEWER DISCHARGE
PUMP
PUMP
AQUEOUS SOLVENT WASTE STREAM

FIGURE 1: COUNTER CURRENT AIR STRIPPING CONFIGURATION

The air stripping treatment design that can be used for removal of waste solvents from aqueous waste streams is a two-tower countercurrent air flow system[2] as shown on Figure 1. A vapor phase carbon system capable of treating up to 6,000 cfm of air with steam regeneration is included in the evaluation.

The air/water ratio for air stripping varies for different types of VOCs.[3] The more common compounds treated by the systems include trichloroethylene, tetrachloroethylene, 1,1,1-trichloroethane, carbon tetrachloride, trans-1,2-dichloroethylene, 1,2-dichloroethane, and 1,1-dichloroethylene. These compounds react differently and have different physical properties such as solubilities and Henry's constant which effect treatment parameters including carbon usage and air-to-water ratios. For purposes of this evaluation an average air-to-water ratio of 50:1 will be used. This value is representative of 99.99 percent removal of trichloroethylene.

The type of packing used for air stripping is critical to performance and treatment efficiency. The packing used in this cost comparison has a density of approximately 65 ft^2/ft^3 and a static loss of approximately 0.4 inches/ft of tower at a flow rate of 1,000 gpm and a hydraulic loading rate of 30 gpm/ft^2.

COST ASSUMPTIONS

The costs used in completing this evaluation are based on actual 1984 construction and operation costs for a full-scale system in operation in the Sacramento, California area. The system has been in operation for two years and treats a combination of the compounds previously listed.

The treatment system includes all plumbing, electrical, and process control as required for a full operational system.

For evaluation of the vapor phase carbon adsorption system, steam is generated using diesel-fired boilers and costs approximately $7.50 per 1,000 pounds. Experience has shown that steam regeneration of the aqueous carbon requires approximately 10 pounds of steam per pound of carbon.

Electrical power is estimated at $0.10 per kilowatt hour, and power requirements for humidity control for vapor phase treatment is based upon a use of 365,000 BTU per hour.

ECONOMIC EVALUATION

To perform economic evaluations and to generate cost optimized design parameters, cost models have been developed[3]. However, a cost model cannot be universally applied without critical evaluation of the specific design, performance, and cost data.

The systems being compared are shown below.

- air stripping
- air stripping with emission controls

The cost assumptions and unit costs for the air stripping systems are applied to the design criteria to develop capital, operation and maintenance, and unit costs using a 10-year, 10 percent, present worth analysis.

Capital Costs

The capital costs discussed in this section are for those elements which are unique to each system. The air stripping system has concurrent air flow with two 6-foot diameter towers with 15 feet of packing in each tower. The system also includes all process controls necessary for automatic operation including steam regeneration of the vapor phase carbon units, should they be required. The vapor phase carbon unit is a 6,000-cfm dual bed system with 5,000 pounds of carbon per vessel. The steam regeneration system operates at 1,000 pounds per hour.

The unit capital costs are summarized in Table 6.

TABLE 6

CAPITAL COSTS FOR
AIR STRIPPING SYSTEMS

AIR STRIPPING:		
. towers with internals ($35,000/each)	$70,000	
. plumbing (flow meters, control valves, pumps)	55,000	
. air (fans and ducting)	15,000	
. process control and electrical	50,000	
Total (without vapor phase control)		$190,000
. vapor phase control (boiler and carbon beds)	320,000	
Total (with vapor phase control)		$510,000

The total capital costs for air stripping are $190,000 without vapor phase control and $510,000 with control.

The operation and maintenance costs for removal of 1 ppm volatile organic compound are summarized in Table 7.

TABLE 7

ANNUAL OPERATION AND MAINTENANCE COSTS FOR AIR STRIPPING SYSTEMS

Item	Air Stripping
Power	$69,430
Carbon	
Regeneration	800
Throwaway	N/A
Steam Regeneration	200
Humidity Control	10,000

The total operation and maintenance costs for air stripping are $69,430 per year without vapor phase control and $80,430 with vapor phase control.

PRESENT WORTH ANALYSIS

The systems are designed and analyzed for a 10-year service life. A present worth analysis provides a method of comparing the various capital and operation and maintenance costs for each system. The present worth costs are summarized in Table 8.

SENSITIVITY ANALYSIS

The unit costs presented in Table 8 are for an influent VOC concentration of 1 ppm. As concentrations increase, carbon use rates also increase which effects the O & M costs significantly resulting in a greater variance in unit costs. Influent concentrations of 2, 3, and 4 ppm were evaluated to determine the effect on the cost comparison. Since the systems capacity remains constant at 1,000 gpm there are negligible capital cost changes. Similarly, experience has shown that air stripping costs remain relatively constant for up to 4 ppm influent concentrations. For a 1,000 gpm system with a 4 ppm influent concentration, the daily air emissions will be higher than allowed on many industrial air permits. For these cases, vapor phase control of air emissions could be accomplished with carbon adsorption units. A cost-sensitivity analysis was completed for influent solvent concentrations up to 4 ppm for treatment by air stripping and by air stripping with vapor phase control. The costs are summarized in Table 9 and presented graphically on Figure 2.

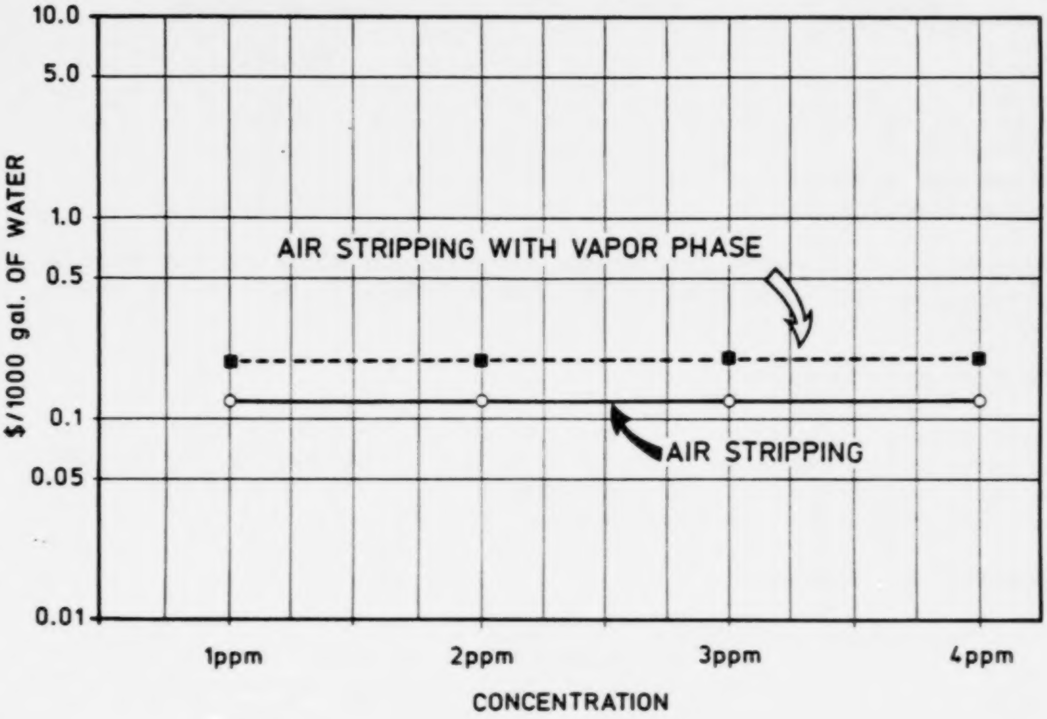

FIGURE 2 COST PER 1000 gal. VS. CONCENTRATION

TABLE 8

COST COMPARISON FOR AIR STRIPPING SYSTEMS

System	Capital Cost	Annual O&M	Present Worth *	Cost per 1,000 gal. Treated for 1 ppm VOC
Air stripping	$190,000	$69,400	$ 616,400	$0.12
Air stripping with vapor phase	510,000	80,400	1,003,980	0.19

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*Ten years at 10% PWF - 6.144.

OPERATION AND MAINTENANCE COSTS

Our experience has shown that manpower requirements are the same for each system; therefore, no manpower costs have been included. It also is assumed that the systems operate continuously. The main operation and maintenance cost for air stripping is power. Should a vapor phase carbon system be required, the additional operation and maintenance costs include power for humidity control, steam production, and carbon replacement.

- Power for treatment system

transfer pump	10 HP
effluent pump	40 HP
turbine fan	25 HP
process controls	10 HP

Total HP requirements = 85 HP

cost = $69,430/year at $0.10/kwhr

- Power for humidity control = 129,600 BTU/hr at 6,000 cfm

cost = $10,000 yr

- Carbon Replacement

Organic loading rate for 1 ppm at 1,000 gpm

Adsorption rate = 0.054 lb VOC/lb carbon

Carbon loading rate = 220 lb/day

- Carbon replacement is required after 100 regeneration cycles,

therefore, 10,000 lb carbon/220 lb/day = 45 days between regeneration cycles replace carbon after 100 cycles = 4,500 days (12 years)

cost of carbon at $1.00/lb = $10,000/12 yr = $800.00/yr

- Steam Requirements = 0.32 lb steam/lb carbon

cost for steam at $7.50/1,000 lb steam and 70 lb steam/day = $200.00/yr

TABLE 9

COST COMPARISON FOR VARIABLE
AQUEOUS WASTE STREAM CONCENTRATIONS

System	Concentration (ppm)	Annual O & M	Present Worth	Cost per 1,000-gal. Treated
Air Stripping	1 - 4	69,400	616,600	0.12
Air Stripping w/vapor phase	1	80,400	1,004,000	0.19
	2	81,430	1,010,300	0.19
	3	82,430	1,016,500	0.19
	4	83,430	1,022,600	0.19

SUMMARY AND CONCLUSIONS

The costs presented herein can be used as guidelines for estimating and budgeting purposes. However, each system has different parameters and should be evaluated independently following similar procedures as presented above. Air stripping also provides great operational flexibility in that the influent concentrations can vary with little effect on the system.

It is concluded that air stripping with or without vapor phase treatment is an effective, flexible method of treatment of aqueous waste streams containing solvent wastes.

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OUTLINE OF
PRESENTATION BY PATRICK W. DENNIS
SOLVENT WASTE REDUCTION ALTERNATIVES SYMPOSIA

OCTOBER 20-21, 23-24, 1986

LEGAL INCENTIVES FOR THE REDUCTION OF SOLVENT AND OTHER HAZARDOUS WASTES

I. Introduction

  A. State regulation of hazardous substances, including solvents, with regard to treatment, storage, transportation and disposal is pervasive and is increasing.

  B. Federal statutes and regulations impact on solvent waste reduction.

    1. RCRA (adopted in 1976 and regulations adopted in 1980).

    2. CERCLA (adopted in 1980).

  C. State regulation of hazardous substances impacts on solvent waste reduction.

  D. State regulation of air and water quality impacts on solvent waste reduction.

  E. Presentation will cover legal (statutory and common law) incentives for solvent and other hazardous waste reduction.

II. Direct Incentives - Restrictions or direct costs on the Treatment or Disposal of Solvents.

  A. State law

    1. Cal. Health and Safety Code § 25122.7 and Title 22 Cal. Admin. Code §§ 66900-66935.

      (a) Complete prohibition on the use of any land disposal method (surface impoundments and landfills) for "restricted" hazardous wastes.

      (b) "Restricted" hazardous waste includes hazardous wastes containing halogenated organic compounds greater than 1000 milligrams per kilogram.

(c) Other liquid hazardous wastes are listed.

(d) Dates: 1/1/85 for halogenated organic compounds and 7/8/87 for organic sludges and solids containing halogenated organic compounds.

(e) There are provisions for a variance.

2. Cal. Health and Safety Code § 25175 - Listing of "recyclable" hazardous wastes which have been found by the DOHS to be economically and technologically feasible to recycle.

   (a) Title 22 Cal. Admin. Code § 66796 lists recyclable hazardous wastes -- the following solvents (used or otherwise) are listed:

      (1) Halogenated solvents: trichloroethane, perchloroethylene, methylene dichloride, chloroform, carbon tetrachloride, and Freons;

      (2) Oxygenated solvents: acetone, methyl ethyl ketone, methanol, ethanol, butanol, ethyl acetate;

      (3) Hydrocarbon solvents: hexanes, Stoddard, benzene,toluene, xylene, paint thinner.

   (b) Suggested methods of recycling: "reclaim, in-plant or through custom solvent reclaimer, by purification process of rectification, ion exchange, absorption, or extraction; or if combustible, use in-plant or sell for use as energy resource for heating, cooling, or power generation."

   (c) If the waste is disposed, DOHS may request from the generator a statement justifying why the waste was not recycled. Generator required to respond. 22 Cal. Admin. Code § 66763.

   (d) Department may, after receiving statement, order recycling. Failure to follow order results in payment of up to two times normal disposal fee. (Potentially, other sanctions are available - see, e.g., Health and Safety Code § 25190 and § 25186(c).)

3. Cal. Health & Safety Code § 25155.5 - requires incineration, or equivalent method, for disposal of following hazardous wastes:

   (a) Hazardous waste with greater than 3,000 BTU per pound by 1988.

   (b) Hazardous waste with volatile organic compounds ("VOCs") in specified concentrations (to be determined by DOHS by January 1, 1987) by 1990.

   (c) Exemption for lack of incineration capacity and recyclable material designated pursuant to § 25175.

   (d) Passed in 1985 as an incentive to reduce volume of highly toxic complex organic chemicals which are disposed.

   (e) Exemptions to requirements of § 225155.5 listed in 25155.6 (including an exemption for the disposal of contaminated soil).

4. Cal. Health and Safety Code § 25208.4 - Prohibits the discharge of any liquid hazardous waste into a surface impoundment after June 30, 1988. There are provisions to apply for an exemption. "Surface impoundment" is defined as:

   (a) An existing surface impoundment which contains a hazardous waste.

   (b) Is located one-half mile upgradient from a potential source of drinking water. ("potential" source is defined in the statute.)

   (c) A natural depression or artificial excavation designed to hold liquids.

   (d) Does not include a "landfill".

5. Cal. Health and Safety Code § 25202.9 - requires annual certification by generator of a treatment, storage or disposal facility that a program has been implemented to reduce volume/quantity of hazardous waste. Further, must demonstrate use of a treatment, storage or disposal method which "minimizes the present and future threat to human health and the environment."

6. Disposal Fees and Taxes.

   (a) Cal. Health and Safety Code §§ 25174-25174.9 - provides for hazardous waste disposal fees. Applies to disposal of hazardous waste onsite or offsite. Schedule of fees developed pursuant to statutory formula - funds used for the operations of DOHS and SWRCB hazardous waste programs.

   (b) Cal. Health and Safety Code §§ 25340 - 25348 - Hazardous waste disposal tax provisions set up a reporting requirement and subsequent tax assessment system for persons who dispose of over 500 pounds of hazardous waste per year. Funds go to the Hazardous Substance Account for the cleanup of hazardous waste sites.

B. Federal laws

1. Resource Conservation and Recovery Act, 42 USC, §§ 6901 *et seq*.

   (a) 40 CFR § 264.314(b) provides that by May 8, 1985 the placement of "bulk or non-containerized liquid hazardous waste or hazardous waste containing free liquids" in any landfill was prohibited.

III. Indirect Incentives - Indirect costs of handling solvents and other hazardous wastes.

A. Liability for Improper Disposal - past and future.

1. Federal law

   (a) Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) 42 USC §§ 9601 *et seq*. Establishing joint and several liability for generators of hazardous waste for disposal sites cleanup costs. Applies offsite or onsite.

      (1) Private rights of action under CERCLA.

      (2) Government cleanups.

   (b) Resource Conservation and Recovery Act ("RCRA") 42 USC §§ 6901 - *et seq*.

   (c) Clean Water Act, 33 USC §§ 1251 *et seq*.

2. State Law.

    (a) State Superfund, California Health and Safety Code §§ 25300-25395.

    (b) Nuisance.

    (c) Ultrahazardous activity.

    (d) Negligence.

B. Hazardous waste management responsibilities.

1. Permitting.

2. Financial responsibility.

3. Manifesting.

4. Enforcement.

C. Hazardous-substance responsibilities

1. Underground storage tank laws-both state and federal.

2. California's Labor Code provisions.

3. "Right to know" local laws.

D. Other:

1. Hazardous waste property designation. California Health and Safety Code §§ 25220-25241.

IV. Legislative Intent and Future Regulations

A. Health and Safety Code §§25244-25244.11. Hazardous Waste Reduction, Recycling and Treatment Research and Demonstration Act of 1985

1. DOHS to conduct study by June 1, 1986 regarding recommendations to the State Legislature on the establishment of a comprehensive program for reducing hazardous waste generation. Includes regulatory incentives, see § 25244.3

2. Generators required to submit report every two years regarding waste reduction § 25244.4

3. Grants available for hazardous waste reduction projects.

B. Upcoming Statewide Toxics Initiative.

C. 42 USC § 6982(r) EPA study regarding feasibility of generators to reduce hazardous waste quantity. Note that a study prepared by EPA is already available.

V. Conclusion.

"VOC EMISSION CONTROL
BY MEANS OF ACTIVATED CARBON ADSORPTION"

BY:

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In November of 1985, President Ronald Reagan and Mikhail Gorbachev, General Secreatary of the U.S.S.R. met to discuss many affairs of state. Although no agreement was reached at the summit meeting on issues such as arms control, there was an agreement reached on environmental control. A little known fact pertaining to the summit was an accord reached concerning a new cooperative effort on projects in the environmental field. Further meetings regarding environmental control between delegations from the U.S. and U.S.S.R. are scheduled for mid-1986. The accord covered a wide range of issues with a focus on the monitoring of global air pollution. At the highest levels of negotiation, the superpowers of the world have agreed to cooperate in an effort to reduce emissions of chloroflurocarbons and hydrocarbons that deplete the ozone layer of the upper atmosphere that protects the earth from the radiation from the sun. It is clear that air pollution is no longer an isolated situational problem, for the problem is one of global proportions. In accordance with the significance of the VOC emission situation throughout the industrial world, the following report details the issue of activated carbon as an organic emission control device.

Two regulatory bodies, the EPA and the Occupational Safety and Health Administration (OSHA), have imposed restrictions on solvent emissions. EPA regulations, some of which are summarized in Table 1, identify the maximum number of pounds of volatile organic compounds (VOC) that may be emitted for every gallon of coating material, less water, for a variety of applications. This legislation generally applies to exhaust streams that are vented to the atmosphere, and are known as the VOC Reasonably Available Control Technology (RACT) regulations. A VOC is defined as any compound of carbon that has a vapor pressure greater than 0.1 mm of mercury at standard conditions (20°C, 760 mm of mercury), excluding carbon monoxide, carbon dioxide, carbonic acid, metallic carbides or carbonates, and ammonium carbonate.

The figures listed in Table 1 are EPA recommended limitations. Each state is free to adopt these restrictions or to opt for more stringent ones. For a state to adopt regulations that are less rigid, however, it must submit technical support to be evaluated by the federal EPA.

OSHA regulations, on the other hand, govern the quality of in-plant air. A summary of these regulations pertaining to solvent vapors is shown in Table 2. The OSHA Concentration Limits for Solvent Vapors identify the parts per million allowable exposure for various solvents. Any time that these limits are exceeded, a solvent recovery unit is applicable.

Carbon adsorption is the generally accepted method for capturing solvent vapors. This process works on the principle that solvent laden air forced through a bed of activated carbon will be purified and acceptable for exhaust to the atmosphere. The solvent molecules actually adhere to the porous surface area of the activated carbon, where they remain in high concentration until forced out by some means of carbon bed regeneration. The regeneration cycle is the most important element of any solvent recovery system, because it determines both the level of energy consumption and the degree of solvent reclamation.

(See following Tables 1 & 2)

TABLE 1
Reasonably Available Control Technology: Limitations for Volatile Organic Compounds

Costing Process	Lb. VOC/Gal. of coating, less water
Can coating	
Sheet basecoat, 2-piece exterior	2.8
Body spray, 2 x 3-piece interior	4.2
End, 2-piece exterior	4.2
Side seam spray	5.5
End-sealing compound	3.7
Coil coating	2.6
Large appliance	2.8
Metal funiture	3.0
Fabric coating	2.9
Vinyl coating	4.8
Auto & light-duty truck	
Topcoat	2.8
Clearcoat	2.8
Primer	1.9
Repair	1.7
Magnetic wire	1.7
Miscellaneous metal products	
Air dry	3.5
Clearcoat	4.3
High performance	3.5
Other	3.0

TABLE 2
1980 OSHA Concentration Limits For Solvent Vapors

Solvent	Maximum allowable exposure (8-hr. weighted average), ppm
Acetone	1000
Benzene	10
N-butyl-alcohol	100
Ethanol*	1000
H	500
Hexane	500
Methylene Chloride	500
MEK	200
Perchloroethylene*	100
Stoddard	500
Toluene	200
Xylene	100

*Changes in these limitations are being considered.

To describe the operating sequence of a solvent recovery system, I have chosen to feature a state of the art solvent recovery system. Other activated carbon systems have somewhat similar operating features, but differ in regeneration process.

The state of the art solvent recovery system is a multi-tank, fixed bed, carbon adsorption module that has been designed with two of industry's most important requirements in mind: Environmental control and energy conservation. An efficient solvent recovery system has taken established, test-proven, carbon adsorption technology and coupled it with individual application design to present industrial clients with the best built, most efficient means of controlling solvent vapor emissions.

The solvent recovery system operates on the principle that solvent-laden air forced through a bed of activated carbon will be purified and acceptable for exhaustion into the atmosphere. The solvent molecules will actually adhere to the porous surface area of the activated carbon where they will remain in high concentration until forced out by some means of carbon bed regeneration, or desorption.

The desorption cycle is the most important element of any vapor recovery system, as this cycle is responsible for determining both the system's solvent recovery percentage (from adsorbed organic) and level of energy consumption. An efficient solvent recovery system utilizes the principles of azeotropic distillation and pressure purge in its unique desorption cycle. By introducing low-pressure, saturated steam (under pressure) to the solvent-laden carbon, the boiling points of the solvent and water are reduced below the atmospheric boiling point of either. This results in almost complete bed regeneration at a substantial reduction in energy cost.

A state of the art solvent recovery system also offers an ability of purging the carbon bed with a water wash or purge. This complete optional package should include all necessary tanks, automatic controls, and system circuitry (pipes, pumps, valves, etc.), to enable thorough washing of the carbon following steam regeneration. Advantages of this unique innovation include: Virtually 100% carbon bed regeneration, immediate control of bed fire potential, and longer life expectancies of the carbon bed and equipment itself.

A typical operating sequence of the solvent recovery system begins as solvent-laden air is directed into the system by a process blower. If needed, the temperature, humidity, and consistency of the air stream can be regulated through the use of a filter, pre-air cooler, or other optional control devices. Diverter valves are used to direct the air stream to the proper carbon adsorption tank.

The solvent-laden air enters the bottom of the carbon adsorption tank and passes through a carbon bed. The bed of specially selected carbon is suspended in the tank by a stainless steel screen. As the air stream flows through the bed, the solvent is adsorbed by the highly porous activated carbon. The purified air then exits through an opening at the opposite end of the tank and is exhausted into the atmosphere. When the carbon bed becomes saturated with solvent and nears a breakthrough stage, incoming solvent-laden air is automatically transferred to an identical carbon adsorption tank in a dual tank system.

Once the incoming air has been diverted to the twin tank, the solvent saturated carbon bed is ready for the regeneration cycle. To accomplish this, the positive seal valves close off the tank at the blower inlet and exhaust ports. Steam valves then open and allow 10 PSIG, 240°F steam to begin filling the vessel. As the carbon bed heats to distillation temperature, the solvent will vaporize and exit through a vapor tube at the bottom of the tank. These vapors will be in combination with a certain amount of distillation steam.

The vapors travel through the vapor tube to a water cooled heat exchanger, where they are condensed, and then collected in a condenser transfer tank. To accelerate solvent and water separation (in the case of immiscible solvents) the mixture should be pumped to the coalescer separator which rapidly separates the solvent and water molecules. The distillate solvent is transferred to the customer storage tank, and the distillate water is drained to sewer or further purified if required.

This regeneration process continues on a timed basis which is determined empirically and adjusted to meet actual application conditions in the field. Field service engineers should aid the customer in arriving at the most efficient and economical system cycle times.

The final step of the regeneration processes the cooling cycle. Clean, ambient air from the dry blower is driven through the carbon bed for a predetermined amount of time to force moisture from the bed. The desired level of bed humidity is dependent upon the solvent(s) involved.

The regenerated carbon bed is now ready to accept incoming solvent-laden air. The combined regeneration and cooling cycles can usually be accomplished in one and one-half hours or less. Through the use of this multi-tank process, the state of the art solvent recovery system is capable of continuous and efficient solvent vapor recovery.

The recovery of vapor, like that of liquid solvent, should not be viewed merely as a compliance tool. The economic benefits of solvent vapor recovery are sometimes outstanding. A firm exhausting 10,000 $Ft.^3$/Min. of toluene from its coating operation, for example, is conceivably losing 400 to 600 lb. of solvent per hr. At a cost of $0.28/lb., the loss approximates $4,500 to $6,700 worth of solvent per week. By choosing a compliance measure other than solvent recovery, these economic benefits will not be realized.

The paint and coatings industry is hard at work to find alternatives to solvent-based coatings. Waterborne paints are acceptable for use in many processes that can bear the 30 to 40 minute air-dry time--for example, in the manufacture of heavy equipment and farm implements--but are out of the question in an automobile plant, for instance. Powder coatings offer an alternative to some manufacturers but are not the answer for all coating applications. When solvents can be reclaimed efficiently and reused in full compliance with federal and state pollution-control regulations, and with no danger to the environment or to human life, the incentive to use alternate, and inferior, coating formulations is sharply diminished.

As a company examines activated carbon technology, one should look closely at design features, safety and instrumentation, process water, energy, carbon/system life, technical support and components. Each of these features will offer competitive benefits or liabilities depending upon the specific technology being examined. As an example of specific points of interest, please consider the following:

1. Tank Construction - All adsorber tanks are manufactured to ASME specifications for unfired pressure vessels (0-15 PSI), Section 25, Paragraph H. Adsorber vessels are thoroughly leak tested. Adsorbers include an inspection port and two (2) carbon removal ports. All covers are bolted onto mating flanges. Safety devices include a rupture disc and vacuum relief system on all adsorbers.

2. Process Flow - Activated carbon type and grade is selected per the application. Isotherms are calculated to determine proper bed design and retention time for maximum performance. Counter flow concept of process air (SLA) and steam injection for regeneration is used. The flow of process air is from the bottom of the carbon bed exiting at the top. Regeneration of the bed is in the opposite direction as steam enters in a downward flow. Solvent vapors exiting from the bottom vapor valve of the adsorber are directed to the condenser. Approximately a 2½" bed of pea gravel is distributed on the support grid. This prevents contact of the activated carbon with the metal surface to eliminate any galvanic corrosion.

3. Transition Duct - The transition duct tee between the dry air inlet valve and the process air inlet valve is constructed of the same material as the adsorber. During regeneration, this duct becomes an extension of the adsorber and is subject to steam and solvent vapor. All internal ductwork between the process blower, dry blower, and adsorbers is provided by DCI.

4. Temperature Monitoring - Temperature monitoring of the carbon bed is indicated at three (3) separate levels; above the carbon bed, the center of the bed, and the bottom of the bed. Thermometers are mounted on the end of the adsorber tanks to easily observe temperatures.

5. Stainless Steel Construction/Modular Design - Modular design of the DYNA 3 Systems are compact sub-assemblies, pre-piped and pre-wired for ease of installation. Capacity and physical size is a determining factor as to whether the system may be fully assembled at our facility. Extremely large DYNA 3 Systems are assembled at the job site. Materials of construction of the DYNA 3 Systems are available in carbon steel, stainless steel, Monel and other metals as required by application specification.

6. Regeneration Process - Regeneration is achieved by means of low pressure steam. 10 PSI steam is introduced while the vapor exhaust is regulated by means of a control valve. This process pressurizes the adsorber vessel to 10 PSI to create 240°F temperature. By regulating steam through the carbon bed, even heat distribution is achieved. This process attributes to a higher percentage of recovery, less condensate in the carbon bed and a substantial reduction of energy consumption compared to atmospheric steaming.

7. Positive Seal Valves - Process air valves of an efficient solvent recovery system should be positive seal, butterfly type, rated at high pressure. All inlet air process valves and exhaust air valves should be air to air operation. Critical duty automatic valves such as steam inlet, vapor outlet, and all liquid process valves should be ball type, spring loaded normally closed. All process air, exhaust air, and circuitry valves should be offered in a wide range of seal and gasket materials to provide compatibility with solvents and heat.

8. Blowers - Two separate blowers should be utilized on the solvent recovery system. The process blower directs solvent laden air (SLA) through the total system. Cooling and partial drying of the bed should be accomplished by means of a separate blower. This cooldown blower introduces ambient air from the atmosphere through the carbon bed. Some solvent recovery systems may use process air (SLA) to cool the bed. Therefore, the hydrocarbons in the air pass through the carbon to the atmosphere while cooling the bed.

9. Pumps - Process pumps of an efficient solvent recovery system should be centrifugal type with John Crane #9 mechanical seals. Stainless steel pump bodies should be made available. Explosion-proof motors should be utilized where applicable.

10. Condensers - Vapor condensers should be high surface area, shell and tube types. Recirculated water, chilled water or a glycol solution can be used as required for the cooling media. Construction material should be dependent upon the type of solvents being recovered.

11. Water Separation - Water separation should be achieved by a patented coalescer/water separator system. The separator system should be available in two (2) types; a 2-stage design to separate two immiscible liquids and a 4-stage design to separate three liquid phases. A disposable carbon filter system, distillation, or air stripper may be necessary to treat the separated water for trace hydrocarbons prior to the disposal or re-use of the water phase.

12. Control System - The master control center of an efficient solvent recovery system should include a full complement of sequence indicating lights, alarms, override functions, and process timers. The standard control panel should be NEMA 12 industrial rating (oil and dust tight) designed for remote operation. A NEMA 7 explosion proof panel should be available when the installation of the control box on the solvent recovery system is preferred and where flammable solvents are being recovered. All components such as pump motors, blower motors, electrical controls, and conduit wiring should be explosion proof (Class 1, Group D, Division 1) when processing flammable solvents.

13. Fire Protection - Fire protection, suppression and monitoring should be offered on all solvent recovery systems processing flammable solvents. Carbon bed monitoring should be achieved by means of a CO monitor. When a critical increase in carbon monoxide is detected (in PPM), a deluge of water should be introduced and the affected adsorber(s) should be isolated.

14. Superheater - The supplier should offer an optional superheater circuit to be installed in the inlet steam line. The superheated system will vaporize high boiling range contaminants which are not affected by the standard 240°F steam required for regeneration. By eliminating the build-up of undesirable higher boiling materials, carbon life will be further extended.

15. Water Purge - A water purge circuit option will provide many advantages and contributes to extended carbon life. The water purge circuit should include a water holding tank, recirculating pump, circuitry piping and automatic controls. Periodically, depending on the degree of contaminants, the carbon bed should be cleansed by means of a water flush. The water purge will remove acids, carbon fines, product dust, and other undesirable material. Once the purge cycle is completed, the cooldown blower can be activated and the purified bed should be ready for on stream operation.

16. Hydrocarbon Analyzer - Hydrocarbon analyzer systems are available to determine bed saturation or breakthrough. The probe should be installed in the exhaust stack, thus providing an accurate reading to activate the regeneration cycle if desired. A chart recorder should be offered to provide a detailed log of the solvent recovery system operation. Steam consumption is reduced as unnecessary regenerations are eliminated.

17. Pre-Air Filter - Pre-Air filtration should be use in most situations. A wide range of media and micron ratings are available. Solid particulates are a detriment to the carbon bed life.

18. Pre-Air Cooling - Pre-Air cooling is required in many applications. Finned coiled heat exchangers should be utilized. The air stream entering the adsorbers should not exceed 100°F.

19. Equipment Lay-Out - The equipment lay-out of a solvent recovery system and supporting equipment may be altered to conform to customers space limitations. Solvent recovery systems should be offered in single and multiple adsorber designs based on operating hours or the customer's requirements. Modular design offers maximum versatility and an efficient installation.

20. Turnkey Installation - Turnkey installation should be available through the supplier on all aspects of the solvent vapor recovery project. When required, a vendor engineer should provide an on-site inspection and prepare a detailed proposal for the total turnkey project.

21. Engineering Specifications - Shortly after a purchase order is received by a supplier, a complete set of detailed engineering drawings and system specifications should be submitted for the customer's approval prior to actual construction. This insures the customer's system will meet all specifications and requirements.

22. Distillation - Distillation of the recovered solvents may be required in some cases. Depending on the application a distillation column may be required to purify the distillate product.

23. Technical Support - Total technical support is offered by DCI on all projects beginning with an engineering evaluation of the specification and request for quotation. Detailed engineering drawings and specifications are submitted for approval prior to manufacturing. An open and continuous line of communication through all phases of the project is considered critical by DCI. Start-up supervision and training of personnel is provided at no charge. A total turnkey capability (including installation) is available when required. A service contract is offered on an annual and renewable basis. Replacement parts and technical field service is available on a 24 hour notice.

An activated carbon solvent recovery system can be designed to achieve nearly 100% operating efficiency. Factors such as air flow, concentration of solvent in the air stream, temperature of the air stream, and contaminants found in the air stream are important issues when designing an activated carbon system. An example of a typical application with a low concentration of solvent in the air stream may be summarized in the following case history:

CASE HISTORY
AIR POLLUTION CONTROL APPLICATION

An aerospace company provides a model case history for the efficiency of a properly designed solvent recovery system in volatile organic compounds (VOC) emission control applications. This project consisted of a two step process. Step one was the installation of a prototype system to demonstrate the capability and reliability of carbon adsorption technology to control emissions in a paint spray booth environment. Step two was the installation of the pollution control equipment (carbon adsorption solvent recovery systems) at three separate facilities;

A testing program was conducted in 1985 at a manufacturing complex located in California. The objective of this testing program was to demonstrate the capability of a properly designed solvent recovery system to achieve 95% efficiency in VOC removal from the spray booth's exhaust stream, and to gather the information for sizing and establishing proper operating conditions for the full scale production units.

A complete pilot testing program was performed at the point of emission to determine the capability of a properly designed solvent recovery system to perform at low VOC concentrations and high air flow rates. The system demonstrated 99+% control efficiency through out the full range of the expected VOC concentrations found in the paint spray booths.

The VOC components from the spray booth exhuast included:

Predominant Components:

Methyl Ethyl Ketone (MEK)
Xylene
1,1,1 - Trichloroethane
Minor Components:
2 - Butoxyethanol
Alphatic Amines
Aromatic Amines
Ethylene Glycol
Toluene

Isopropanol
Methyl Isobutyl Ketone
Butyl Acetate
Cellusolve Acetate
Cyclohexanone

The most important results collected from the pilot testing were:

1) Information for the proper design of the carbon bed to meet state and federal VOC emission requirements for each plant location.

2) Proper steaming rates and cycle times required to regenerate the carbon bed.

3) Proper air velocity through the carbon bed.

4) Exact cool down cycles required for the carbon bed.

The proper design of carbon beds resulted in great cost savings. The energy consumption was considerably decreased with the proper steaming rates and cycles. Also, since the blend of solvent recovered was not usable, proper arrangements for the solvent disposal were made for the production systems.

In conclusion, carbon adsorption was proven to be effective in removing the required 95% VOC emitted during paint spray operations for all tested concentrations. The result of these testing programs was used in design and sizing of the actual production units in the second stage of the project.

TABLE B-1

This table specifies the recovery system efficiencies calculated based on the predominant solvent in the paint samples tested. The efficiency was calculated as follows:

$$\% \text{ Efficiency} = \frac{\text{Inlet PPM} - \text{Outlet PPM}}{\text{Inlet PPM}} \times 100$$

These concentrations have been determined by an analytical laboratory. Bag samples of the inlet and outlet air into and from the unit have been collected for this purpose. The efficiency for some tests are not calculated due to uncertainty in laboratory test result. This problem developed because of the difficulty in the handling of the sample bags and loss of the sample gas (See the report of analytical results).

TABLE B-1: ANALYTICAL LABORATORY RESULTS FOR SAMPLES COLLECTED

Paint Sample Tested	Date	Predominate Solvent	Inlet PPM	Outlet PPM	Efficiency %
#1	11/85	MEK	0.2	Less than 0.1	---a
#2	11/85	MEK	1.2	Less than 0.1	92
#3	11/85	Isopropyl Alcohol	0.3	Less than 0.1	---
#4	11/85	Isopropyl Alcohol	1.1	Less than 0.1	91
#5	11/85	Isopropyl Alchohol	1.0	Less than 0.1	90
#6	11/85	MEK	0.4	Less than 0.1	---
#7	11/85	MEK	1.3	Less than 0.1	94
#8	11/85	MEK	1.7	Less than 0.1	---
#9	11/85	MEK	9.0	Less than 0.1	98
#10	11/85	Ethyl Acetate	0.3	Less than 0.1	---
#11	11/85	Ethyl Acetate	1.0	Less than 0.1	
#12	11/85	Ethyl Acetate	0.2	Less than 0.1	
#13	11/85	Ethyl Acetate	Less than 0.1	Less than 0.1	
#14	11/85	N/A	N/A	N/A	---
#15	11/85	N/A	N/A	N/A	---
#16	11/85	III Trichloro-ethane	6.3	0.2	96
#17	11/85	III Trichloro-ethane	34	0.2	99+

TABLE B-1: Continued

Paint Sample	Date	Predominate Solvent	Inlet PPM	Outlet PPM	Efficiency %
#18	11/85	III Trichloroethane	Less than 0.1	Less than 0.1	---
#19	11/85	N/A	N/A	N/A	---
#20	11/85	Isopropyl Alcohol	Less than 0.1	Less than 0.1	---
#21	11/85	Ethyl Acetate	Less than 0.1	Less than 0.1	---
#22	11/85	III Trichloroethane	1.4	0.4	---
#23	11/85	Ethyl Acetate	Less than 0.1	Less than 0.1	---
#24	11/85	III Trichloroethane	2.2	8.1	---
#25	11/85	III Trichloroethane	8.7	1.5	---
#26	11/85	III Trichlorethane	16	0.2	99

TABLE B-2

This table presents the activated carbon unit efficiencies for the solvents with the highest concentration detected in the sample bags.

TABLE B-2: EFFICIENCY FOR THE SOLVENTS WITH THE HIGHEST CONCENTRATION DETECTED IN THE SAMPLE BAGS.

Highest Solvent (PPM)	Date	Inlet PPM	Exhaust PPM	Efficiency %	
MEK	11/85	9.0	Less than 0.1	99	
Isopropyl Alchol	11/85	1.1	Less than 0.1	91	
Butyl Acetate	11/85	33	Less than 1	97	
Ethyl Acetate	11/85	3.0	Less than 0.1	97	
III Trichloro-ethane	11/85	34	0.2	99	
Butyl Cellusolve	11/85	2.9	Less than 0.1	97	

The steam pressure purge activated carbon adsorption/regeneration process compliments most VOC emission control applications. The technology offers the highest possible degree of adsorption efficiency, thereby, satisfying compliance requirements. In most situations, a reasonable degree of economic justification is achieved by installing an efficient solvent recovery system. However, potential users of activated carbon systems should not expect dramatic economic benefits. The primary purpose of a solvent recovery system is to remove VOC from process air streams and, therefore, fulfill compliance requirements.

If steam is not available for regeneration purposes, or if moisture content in the recovered product is a problem, then a potential activated carbon user may want to examine a hot oil convection regeneration process. Listed below is a process description of a typical application requiring the use of hot oil and a nitrogen blanket:

Adsorption Cycle

A convection regeneration solvent recovery system will receive solvent-laden air from process equipment. This air will be forced through a properly sized bed of activated carbon to ensure compliance with state or federal air pollution control regulations. A hydrocarbon analyzer should monitor volatile organic compond (VOC) content in the exhaust air stream from the carbon adsorber tank. When this monitor detects a predetermined concentration of hydrocarbons, it will automatically switch the air stream to a second bed and prepare the loaded bed for regeneration. All inlet exhaust openings to the tank should be closed off with 100% sealing butterfly valves.

Regeneration Cycle

Hot oil at 400°F is introduced into convection coils located within the carbon bed. Heat from this oil will thermally drive the adsorbed solvents from the carbon into a vapor state within the tank. Concurrently inert nitrogen will be introduced to maintain a safe concentration (approximately 10-25% LEL) of solvents in the tank atmosphere. This vapor mixture will be drawn from the tank via a positive displacement rotary lobe pump. Automatic monitoring will introduce additional nitrogen if necessary to maintain a safe working environment. Vapors from the pump will be directed through a cooling water fed condensing coil to recover the solvent vapors. The non-condensed nitrogen will be recycled to the adsorber vessel for conservation of nitrogen consumption. Regeneration cycle time should be timer-controlled and based upon optimum solvent recovery vs. cost of energy over time. At the end of the regeneration cycle, ambient air will be passed through the adsorber to cool the carbon bed and vessel walls back to adsorption operating temperatures. This adsorber will then be ready to come on line when the hydrocarbon analyzer detects breakthrough in the carbon bed on stream at the time. The cycles of adsorption, thermal regeneration, and cool down will be continuous and automatically controlled.

Recovered Solvent Handling

Condensed liquid solvent will be collected from a trap sealed condenser. Water content of this recovered solvent will be limited to that amount of relative humidity adsorbed from the inlet air stream and vaporized during regeneration. This water content can easily be maintained to less than 5% due to the carbon's higher affinity for solvent vapors than water. Desiccant filters can be used if necessary to achieve higher purities. A clean solvent pump and float controlled transfer tank will allow this stream to be directed to any customer designated storage automatically.

The New York Times recently reported that the National Aeronautics and Space Administration confirms that activities ranging from the burning of fossil fuels to emissions of chlorofluorocarbons and hydrocarbons are changing the atmosphere. The warming of the earth from pollutants in the atmosphere is blocking the escape of heat from the earth's surface. This greenhouse effect is expected by scientists to have far-reaching social and economic consequences. They say it could turn food-producing areas into dust bowls and melt the polar ice caps, causing flooding in the coastal areas. It is also assumed that ozone depletion, by allowing harmful radiation from space to reach the earth's surface, could increase human cancer and damage plant and animal life.

The report said that given the incomplete knowledge of the chemical relations among ozone, climate and the trace gases emitted by human activities, that we should recognize that we are conducting one giant experiment on a global scale by increasing the concentrations of trace gases in the atmosphere without knowing the environmental consequences. It is indeed a dangerous experiment since we know that the earth's protective ozone shield is being depleted by chlorofluorocarbons and hydrocarbons.

In view of the magnitude of the problem, you are urged to study your specific application and eliminate uncontrolled organic emissions by utilizing the best available technology which in most situations is an efficiently designed state of the art activated carbon solvent recovery system.

This greenhouse effect is expected by
Space Administration confirms that activities ranging from the burning

WASTE MINIMIZATION AUDITS

by
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Regulations governing industrial and hazardous waste management have evolved over the past ten years into a series of complex, overlapping procedural hurdles. From the federal government alone, there are currently over 30 federal statutes that address environmental protection and pollution control. Increasingly, federal, state, and local regulations are moving toward minimizing, if not eliminating in selected cases, the emission, discharge, generation, or off-site disposal of many types of industrial waste compounds.

Audits are proving to be increasingly effective, practical management tools in assisting industry to marry regulatory compliance requirements with day-to-day operating reality. Audits allow industry to:

- Evaluate and verify environmental compliance;
- Increase employee awareness to regulatory requirements and corporate compliance policy;
- Ensure management accountability;
- Effectively plan capital, operations and maintenance budgets;
- Minimize environmental liabilities associated with acquisitions and divestitures;
- Evaluate and improve operating practice; and
- Police itself and make needed corrections before violations are cited and penalties imposed.

This paper focuses on waste minimization audits. Unlike environmental audits, waste minimization audits concentrate not only on environmental compliance, but on how waste generating activities that may in fact be in compliance can be improved to minimize waste generation. This paper provides a brief background on the importance and necessity of an audit, a description of the key elements of an audit, and a discussion of post audit activities and considerations.

BACKGROUND

Audits are effective tools in identifying, assessing and minimizing risk from:

- A regulatory program that increasingly limits the types and amounts of wastes generated, their method(s) of disposal, and imposes stiff civil and criminal penalties for non-compliance;

- A collapsing insurance market; and
- The application of liability versus negligence standards by the courts in hazardous waste cases.

Federal regulation, primarily through the Resource Conservation and Recovery Act (RCRA) and subsequent amendments, has established a comprehensive regulatory and permitting program for the generation of hazardous waste. RCRA defines hazardous waste and mandates "cradle-to-grave" tracking of all affected waste streams.

RCRA's mandate was recently expanded when the bill was reauthorized in 1984. Among other provisions, the bill:

- Eliminates the small quantity generator exemption for hazardous waste generators of 100 to 1,000 kg per month;
- Bans certain wastes from land disposal (and requires EPA to evaluate and promulgate regulations banning additional wastes from land disposal);
- Regulates the use, cleanup and monitoring of underground storage tanks;
- Requires landfills and surface impoundments to be fitted with double liners and leachate collection systems;
- Requires all RCRA permit applicants to certify that they have established programs to reduce the amount and toxicity of wastes being generated;
- Requires the inspection of all hazardous waste facilities at least once every two years; and
- Regulates the blending and combustion of waste fuels that contain hazardous substances.

The State of California, through the Department of Health Services, has established a hazardous waste regulatory structure that in many ways is more comprehensive than the federal RCRA program. Most notably, California, in 1981, established a Land Disposal Restriction Program. The program is designed to ban specific wastes from land disposal according to a defined schedule. Already banned are liquid wastes containing free cyanides, toxic metals, PCBs, and halogenated organic compounds. In concert with the Land Disposal Restriction program, the state is moving aggressively to encourage waste minimization.

Both the federal and state regulatory programs impose stiff civil and criminal penalties for noncompliance. Penalties can include fines of $25,000 a day or $250,000 and imprisonment. Recently, both the federal government and jurisdictions in California have placed increasing emphasis on criminal sanctions as an enforcement tool. These have been directed at "responsible corporate officials" at the highest level reachable.

Traditionally, industry has been able to meet its obligations and shield liabilities through insurance coverage for general, professional and pollution liabilities. Recent changes in the insurance market have diminished, if not eliminated, much of this coverage. Comprehensive General Liability (CGL) policies traditionally offered coverage that included "sudden and accidental" pollution provisions. Since the early 1970's, most CGL policies have excluded coverage of damages caused by gradual releases of hazardous substances.

In response to demand for liability coverage for pollution releases that are not "sudden or accidental", Environmental Impairment Liability (EIL) insurance was offered. However, following court decisions blurring the distinction between "sudden and accidental" and "gradual" releases, and increasing financial pressures on the insurance industry, both forms of coverage have become difficult to obtain. Professional liability coverage is likewise becoming constrained and, if offered, usually excludes pollution liability.

Without adequate insurance, the court's application of strict liability, and joint and several liability to hazardous waste management and cleanup cases exposes industry to considerable financial risk. Strict liability implies that certain parties may be held liable for the costs of cleaning up toxic substances without regard to the care exercised. These parties may include: owners and operators of treatment, storage, and disposal facilities; persons who arranged for the transport of hazardous substances; any person who accepted any hazardous substance for transport; and contractors. In other words, such parties are liable regardless of whether negligence or other wrongdoing was involved during their respective management of the materials. There are few defenses available under this legal theory.

Joint and several liability provides that each defendant is independently responsible for the entire cost of a hazardous substances release cleanup. Consequently, joint and several liability creates the situation in which a defendant that merely contributed to an incident may be responsible for the entire cleanup cost if other defendants are unknown, unidentified, or financially unsound. However, where more than one responsible party is identified, the courts can apportion responsibility for cleanup costs. Firms with substantial financial resources are particularly vulnerable under a "deep pocket" approach to compensation and cost recovery.

ARE AUDITS NECESSARY AND REQUIRED?

At the present time, although strongly encouraged, audits are not required by law. As part of good management practice, however, increasing numbers of firms are using audits to shift from a mode of reactive environmental management to a proactive, anticipatory mode. In other words, before fines are imposed or corporate officers taken to court, firms are using audits to identify and correct problems.

Audits can and should be viewed as risk control programs. The objective is to control and limit liability. Too often in the past corporate management for large firms has relied on each of its operating groups to independently monitor and comply with environmental regulations. Results were at best mixed. Corporate management often had little handle on the nature and extent of environmental activities at its facilities. Employee awareness and sensitivity to environmental issues at the level that often generates the problems - the working level - was lacking.

Smaller firms do not have the resources of large firms. They have not been able to turn to corporate environmental departments for regulatory updates and guidance, and they often do not have the staff to monitor compliance.

Audits offer not only the opportunity to flag and correct current regulatory problems but review operating practice as well. As the regulatory environment continues to move in a direction of discouraging the generation and land disposal of toxic wastes, there is increasing incentive to assure that industry operates as efficiently as possible. The benefits can be quite tangible and go beyond meeting corporate responsibilities. Production costs and disposal fees can be cut substantially. The longer-term potential liabilities of off-site disposal can be significantly diminished, if not eliminated.

WHAT IS INVOLVED?

Waste minimization has been referred to as "better utilization of raw material" or as "yield improvement". The better the product yield, the less waste is generated. As the management and disposal of hazardous industrial wastes becomes an important national issue, waste minimization is increasing in prominence. The 1984 federal Hazardous and Solid Waste Amendments (HSWA) established, as national policy, that hazardous waste generation should be reduced or eliminated as expeditiously as possible whenever practicable.

Waste minimization audits focus on three types of activities that reduce the volume and/or toxicity of hazardous waste. In order of preference, these are: (1) source reduction, (2) recycling, and (3) treatment. Source reduction, the most preferred waste minimization approach is defined as any activity that reduces or eliminates the generation of hazardous waste at its source within a process. Recycling, which covers both reuse and reclamation, refers to any activity that reduces hazardous waste volume and/or toxicity with the attendant generation of a valuable material that is subsequently utilized. Treatment, the least preferred category in the hierarchy of waste minimization activities, refers to any activity that reduces hazardous waste volume and/or toxicity without attendant generation of a valuable material.

Following are the key elements involved in a waste minimization audit:

1. Establishing Goals and Objectives
2. Selecting the Audit Team
3. Pre-Audit Activities
4. Performing the Audit
5. Post Audit Activities

ESTABLISHING GOALS AND OBJECTIVES

The focus of a particular audit should be clearly elucidated in advance of the site visit. Goals and objectives might include any or all of the following:

- Environmental/Permit Compliance
- Information Transfer
- Employee Awareness/Training
- Management Accountability
- Operating Practice Review
- Records Review
- Materials Balance/Flow Tracking and Reporting
- Liability Definition (from past, ongoing and potential practices)
- Liability Prevention
- Waste Minimization

SELECTING THE AUDIT TEAMS

Audits can be performed by in-house personnel or by outside contractors. There are advantages to using either group or a combination of both. Factors to consider include:

- Staff availability,
- Knowledge of the facility,
- Knowledge of applicable environmental regulations,
- Objectivity,
- Knowledge of Waste Minimization Techniques, and
- Cost.

In-house audit teams can be used to advantage for:

- Training and increasing employee awareness;
- Establishing management and staff accountability;
- Developing ongoing, consistent, company-wide operating procedures; and
- Tapping the day-to-day operating knowledge of plant or facility personnel.

Consultants can be used effectively where:

- Small or medium-sized firms lack the necessary resources to conduct an audit;
- Third-party objectivity is important;
- A broad experience perspective would be helpful in reviewing operating practice and establishing management strategy;
- Management of data results are at issue - for example, use of a contractor through corporate counsel for attorney-client privilege; and
- Firms would like assistance in setting up and/or monitoring an in-house audit program.

PRE-AUDIT ACTIVITIES

Pre-audit activities include:

- Preparation of audit questionnaires, checklists and support materials;
- Audit team meeting(s) to develop work plan(s);
- Notification of plant manager(s) and appropriate personnel; and
- Site records reviews.

For large or multi-facility firms, previsit questionnaires can be effective in profiling a facility and familiarizing the audit team with the types of environmental programs, operations, permits and materials that are in place. The previsit questionnaire is also important in specifying the particular types of information and operations to be reviewed so that the facility manager will be prepared.

Typical items to be covered in a previsit questionnaire include:

- Plant/facility organization (including environmental and waste management responsibilities),
- Descriptions of the operations/activities at the site,
- Descriptions of proposed changes to the plant
- Descriptions of pollution prevention facilities and programs,
- Descriptions of areas that may be out of compliance or requiring special attention,
- Descriptions of areas of concern (including regulatory uncertainty), and
- A listing of key permits and regulated activities.

PERFORMING THE AUDIT

There are two key elements to the successful performance of an audit - the audit manual and the site visit protocol. The manual provides a road map and guide to the facility to be audited. It includes the pre-visit questionnaire, the auditor's guide and the audit checklists.

As just noted, the pre-visit questionnaire profiles the facility to be audited and acquaints the audit team with its mission. It also provides facility personnel with a sense of the issues and items to be explored during the audit.

The audit guide is intended to assure a consistent approach from audit to audit and among auditors. The guide outlines goals and objectives, approach and protocols, interview and record review procedures, and how results should be reported.

Audit checklists are developed to focus the auditors to the specific goals and objectives of the audit. The checklists consist of various series of questions targeted at regulatory requirements, operating practice and organizational controls. Specific questions vary depending on the goals of the audit and the facilities or operations being reviewed.

Waste minimization audits (in addition to a regulatory compliance review) should target a facility's waste streams, the operations generating those wastes, and areas with potential for waste minimization.

Each waste stream from a facility should be identified and characterized. The following items should be covered:

- Waste Stream Type: Direct (Process Wastes)
  Fugitive (Evaporative)
  Secondary (Spend cleaning solvents)

- Waste Characterization

- Quantity

- Flow (Continuous vs. Intermittent)

- Media Affected (and How): Air
  Water
  Land

With a profile of a facility's wastestreams, a closer look at plant operations in the context of waste minimization is more meaningful. The audit should focus on the following:

1. SOURCE REDUCTION POTENTIAL

    A. Source Controls (In-Plant Changes)

        i. Input Materials - Use and Alteration
            a. Material Purification
            b. Material Substitution

- ii. Equipment/Technology - Use and Modification
  - a. Layout
  - b. Operational Settings
  - c. Process Changes
  - d. Automation
  - e. Materials Conservation
  - f. Water Conservation
  - g. Energy Conservation
  - h. Treatment

- iii. Operating Practice
  - a. Personnel Practices
  - b. Procedures
  - c. Loss Prevention
  - d. Material Handling and Storage
  - e. Waste Stream Segregation

- iv. Organization and Management

B. Product Alteration

- i. Product Sustitution
- ii. Product Conservation
- iii. Product Composition Alteration

2. RECYCLING
   - i. Reuse
   - ii. Reclamation
   - iii. Separation and Recovery

3. TREATMENT
   - i. Type:
     - a. Chemical
     - b. Biological
     - c. Thermal

   - ii. Efficiency

   - iii. Waste Stream
     - a. Quality
     - b. Quantity

   - iv. Operating Requirements
     - a. Materials
     - b. Energy
     - c. Personnel

Specific checklists and questionnaires tailored to these items should be prepared in advance of the site visit. The audit team should be thoroughly familiar with the audit manual before calling on the facility. A key to the success of an audit is advance preparation.

Site visit protocols will vary from audit to audit and facility to facility. Key factors to consider include:

- The team should have ready and free access to staff, records and the facility.
- Plant/facility management should be available for ongoing consultations, guidance, and coordination.
- Key plant staff should be available for interviews, briefings on their responsibilities and operations, records retrieval, and plant tours.
- Process flow diagrams (PFDs), heat and water balances, piping and instrumentation drawings (P&IDs), waste manifests, permits, and environmental documents, where available, are particularly useful in identifying waste generation points.

POST AUDIT ACTIVITIES

Before conducting an audit, be prepared to respond to its findings. In performing any compliance related audit, there is a risk of finding information concerning noncompliance or previously unknown problems. Discovery of this information if not acted upon could lead to criminal penalties against management.

Waste minimization audits often do not point to noncompliance issues so much as they target areas for proactive waste management. Through long experience with existing production processes and waste management practices that have relied on land disposal, management may find it difficult to justify change, especially in the absence of definitive regulations. A waste management audit is only the initial step to a successful program.

The data collected from the audit should be screened and a set of waste minimization options developed. The most promising options should then be subjected to a feasibility study, during which technical viability, ease of implementation, cost-effectiveness, and environmental applications are evaluated and compared. With the most practical and profitable option(s) chosen and in place, performance should then be monitored so that achievement of objectives are assured.

Many firms are finding that the benefits to implementing waste minimization audit findings are substantial:

- Where capital costs are involved, the payback period is typically short - one to two years.
- Quite often, changes in operating practice alone can cut waste generation substantially.
- Profits increase as waste disposal costs are cut and raw material utilization improves.
- Employee awareness increases reducing the potential for compliance violations and the potential liabilities associated with unexpected releases, and worker and public exposures.

In summary, the potential for benefit from an audit is substantial in meeting regulatory requirements, identifying and controlling liability, maximizing profits, and in demonstrating to the government and the public that a good faith effort is being made to be a responsible corporate citizen.

H. Ray Kerby

September 5, 1986

LIQUID WASTE MINIMIZATION AT IBM SAN JOSE

LIQUID WASTE MINIMIZATION AT IBM SAN JOSE

The IBM San Jose site is located in the Santa Clara Valley, 45 miles south of San Francisco. The main site covers approximately 500 acres and employs about 9300 people.

IBM San Jose performs diverse operations that include both wet and dry manufacturing, plus research, development, and administrative support. This paper will deal with the wet portion of the manufacturing and development that occurs on the site. It will discuss some of the processes, the waste outflow, what is being done to reduce this waste today, and some of the things that are planned to reduce it in the future.

Since 1971 IBM has had a corporate policy which states that:

- We will meet or exceed government regulations concerning toxic waste
- We will minimize terminal waste disposal.
- We will also utilize non-polluting methods in treating our waste.

A Corporate Facilities Practice, issued in 1973, established the waste-management hierarchy of:

- Minimization
- Recycling
- Incineration
- Detoxification
- Secure Landfill

With both of these things in mind, IBM San Jose, which had been hauling all its waste off-site, began in 1978 to construct an industrial waste-water treatment facility. Completed in 1979 it had a 250,000-gallon per day capacity and the capability to treat industrial waste. The plant was expanded and upgraded in 1983 and at present is capable of handling 1,250,000 gallons of industrial waste per day. The expanded plant now consists of three separate systems: The concentrate plant, the organic plant, and the rinse plant. The objective of the expansion was to provide increased treatment capacity, separate treatment of rinse waste which could be reclaimed and reused, and treatment of diluted organic waste streams. If we look at 1985, our annual volumes for liquid were:

1.4 million gallons	Scrubber waste water (5% solvents)
0.5 million gallons	Waste solvent (0-50% water)
0.2 million gallons	Contaminated rain water
0.1 million gallons	Acid or base waste

To break these down in more detail, the waste streams consisted of:

(a) Coating wastes containing polar and non-polar solvents, iron oxide particles, and epoxy/phenolic resins (dilute)

(b) Scrubber wastes comprised of 95% water, freon, alcohols, and miscellaneous other solvents.

(c) Mixed solvents consisting of 0-25% water, alcohols, freon, aromatic, and chlorinated solvents

Scrubber waste (dilute solvents) are one of the more expensive materials to handle. They also provide the best opportunity for waste treatment and reuse. There was a time when reclaimers would buy your waste for the chemicals in it. Now you pay them to haul it away. Being able to treat this waste permits us to reuse 260,000 gallons per day as make-up water in our cooling towers. This reuse amounts to savings of $30,000 per year in water and pump costs. Not having to dump that waste in the San Jose sewer system saves us $100,000 per year in sewer charges. Savings from not having to haul it off site contributes $740,000 per year in disposal costs. Excluding operating costs, this totals to a saving of $870,000 per year.

Granted not everyone can afford or even needs a waste-treatment facility, but source reuse or elimination of chemicals can save a considerable amount of money. In order to do this, however, accurate waste profiles need to be developed and maintained. The generating entity must be held responsible for its own waste management. Then applicable alternatives can be developed, evaluated, and implemented. At IBM, we have implemented the procedures I have mentioned and have plans that will reduce our liquid chemical waste by 75% over the next three years. By 1993, we are anticipating reducing our haul-off by 85%. And no, not by eliminating manufacturing! In fact, the reduction includes a 15% per year manufacturing growth factor over this time period.

I've covered briefly the handling of our dilute waste streams in the Industrial Waste Water Treatment Facility and the associated savings. I would like now to mention some of

THE OTHER AREAS WE'RE WORKING ON. RAIN WATER IS ONE SIMPLE ITEM THAT HAS CREATED HANDLING NEEDS AND COSTS. THAT RAIN WATER WHICH ACCUMULATES IN CHEMICAL CONTAINMENT AREAS FORMERLY HAD TO BE HAULED OFF THE SITE. WE NOW TEST IT FOR CONTAMINANTS AND DISCHARGE IT TO THE SEWERS IF ESTABLISHED CRITERIA ARE MET. CHANGES IN OUR INDUSTRIAL WASTE WATER TREATMENT FACILITY WILL PERMIT US TO TREAT THIS WASTE WHEN IT DOESN'T MEET CRITERIA.

THE ABILITY TO DISPOSE OF A FLUORINE-CONTAINING COMPOUND IS DIFFICULT AND WILL BECOME MORE SO. FREON, WHICH IS CRITICAL TO THE SITE'S MANUFACTURING PROCESSES, GETS MIXED WITH DEIONIZED WATER DURING ITS USE AND IS COLLECTED AT OUR CENTRAL TANK FARM IN WASTE TANKS. FROM THERE IT IS HAULED OFF TO A RECLAIMER. IN THE FUTURE, WATER WILL BE SEPARATED FROM THE FREON WASTES AND THE WASTES WILL BE SENT BACK TO THE MANUFACTURER WHERE THE RECLAIMABLE FRACTION WILL BE SEPARATED OUT AND THE RESIDUE DISPOSED OF BY INCINERATION. OUR VOLUME LAST YEAR WAS APPROXIMATELY 250,000 GALLONS. THIS YEAR WE EXPECT IN EXCESS OF 300,000 GALLONS.

WE FEEL THAT BY IMPLEMENTING THE TREATMENT OF THESE GROUPS OF WASTE, WE WILL, AS STATED PREVIOUSLY, BE ABLE TO REDUCE THE SITE'S LIQUID CHEMICAL WASTES BY 75% OVER THE NEXT THREE YEARS. MORE IMPORTANT, THIS GROUP OF WASTES ARE LIKELY TO BE NO LONGER DISPOSABLE BY TRADITIONAL METHODS IN THE NEXT 18 TO 24 MONTHS.

OTHER AREAS OF REDUCTION WILL COME FROM RETURNING ALCOHOLS/ KETONE, AND NMP WASTES BACK TO SUPPLIERS FOR REUSE. WE HAVE REACHED AGREEMENTS WITH THE MANUFACTURERS, BUT WE MUST STUDY THE PROCESS AND THE WASTE STREAMS TO REDUCE NON-PROCESS CONTAMINATION AND CROSS CONTAMINATION. WASTE STREAMS MUST

BE SEPARATED, AND THE COST TO DO THIS EVALUATED. THESE ARE FUTURE PLANS, WHICH ARE VERY IMPORTANT TO FURTHER REDUCING THE CURRENT WASTE STREAM. WE FEEL THIS PROGRAM WILL BE JUSTIFIED AND IMPLEMENTED WITHIN THE NEXT FIVE TO TEN YEARS.

OTHER PROGRAMS BEING CONSIDERED FOR IMPLEMENTATION DEPEND ON SOLID WASTE REDUCTION. SOME OF THESE PROGRAMS WILL ALSO ASSIST IN OUR REDUCTION OF LIQUID WASTE.

I'VE COVERED WHAT IBM'S POLICY IS AND I'VE TRIED TO SHOW WHAT IBM SAN JOSE IS DOING TO MEET THESE GOALS. WE DO HAVE COMMITTED PLANS AND STEADY PROGRESS IS BEING MADE. WE FEEL WE HAVE GOOD PROGRAMS TO EVALUATE AND IMPLEMENT, AND BEING FULLY COMMITTED TO WASTE REDUCTION, WE SHOULD SUCCEED.

VENTURA COUNTY'S HAZARDOUS WASTE VOLUME REDUCTION/ALTERNATIVE TECHNOLOGY PROGRAM

by

DONALD W. KOEPP

Ventura County's industries produce over 38,000 tons of hazardous waste annually, of which approximately 85% was disposed of in landfills in 1985. In order to reduce this dependency on land disposal and to project future treatment and disposal needs for industries in the County, Environmental Health conducted waste audits and surveys of companies using land disposal in order to:

1. determine the exact chemical composition, quantities, and disposition of wastes produced;
2. determine if these companies were expecting to make major changes in waste stream generation;
3. ensure that recycling, reuse, and waste reduction methods were employed when possible;
4. identify major barriers to on-site volume reduction or treatment;
5. project future treatment and disposal needs of industries within the County;
6. assist each company in the development of a Volume Reduction Plan as required by RCRA.

Analysis of waste generation patterns demonstrated that in 1985, 75 companies in Ventura County produced 95% of all the County's hazardous waste that was disposed of in landfills. Industries disposed of 76% of the total hazardous waste produced at Casmalia Resources in 1985. The major waste streams were oil field production wastes, acids, and aqueous and alkaline solutions that contained between 90 and 98% water.

A questionnaire was sent to the 75 companies relying on land disposal to determine if these industries plan to make any major changes in waste stream generation. Projections for future countywide hazardous waste management needs were made from the results of the questionnaire.

The results show that approximately one-half of the 75 major generators have found alternatives to land disposal for their hazardous wastes. Hazardous waste generation is projected to be 30 to 40 percent less in 1986 as compared to 1985. This projection does not include contaminated soil from hazardous waste sites or wastes from new industry. This amount can be further reduced by treating all liquid wastes and dewatering sludges.

Ventura County generators produce less than 2% of the Southern California Area Government regional waste. Ventura's waste profile is also substantially different from the regional waste profile, indicating regional treatment and disposal needs will not meet local generator requirements. Generators may still rely on Casmalia Resources for treatment and disposal of hazardous waste however, it appears that the quantities of liquid hazardous waste will be substantially reduced by on-site treatment methods.

The questionnaire results revealed that the major barriers to hazardous waste volume reduction are lack of information, financial constraints, and regulatory impediments. Smaller firms, especially, are faced with problems such as the lack of technical personnel to investigate waste reduction and capital costs for treatment technologies.

The immediate results of several of the waste audits conducted by Environmental Health provided solutions for simple, available, and low-cost methods to reduce or eliminate all generation of hazardous wastes. Industries were found to be disposing of recyclable wastes, manifesting non-hazardous wastes, and unnecessarily generating wastes. The first step in volume reduction typically involves relatively unsophisticated technical approaches such as good housekeeping, separation of wastes, and water conservation. Although technically simple, these steps have the potential for achieving substantial waste reductions. It was also found that attitudes toward change, regulatory issues, costs of land disposal, and availability of information about existing waste reduction methodologies were significant in affecting corporate decisions about waste generation.

The results of this study further conclude that the major portions of industrial effort in the County is now in the initial phase of hazardous waste reduction. Development of hazardous waste reduction efforts can be expected to improve over time as the major obstacles to volume reduction are addressed.

In order to further reduce waste volumes, on a Countywide basis, Environmental Health will continue to disseminate information to generators, engineers, and plant operators on waste reduction techniques and alternatives. Individual firms will be targeted to implement waste reduction practices and new technologies. Financial resources for companies needing more capital intensive technologies will be sought. Industries will also be encouraged to share information about waste reduction successes. Finally, the Department will assist in overcoming the regulatory barriers that impede waste reduction efforts in order to provide companies with the most technically feasible and environmentally sound waste treatment methods.

PRETREATMENT OF SOLVENT-CONTAMINATED WASTEWATER FOR SEWER DISPOSAL

M. Philip Lo, Gilbert C. Chang and Leon S. Directo
Los Angeles County Sanitation Districts

TYPES OF ORGANIC SOLVENT

Organic solvents are essential for a number of industrial manufacturing. The types of solvents usually found in wastewater are as follows:

Chlorinated Solvents: methylene chloride, 1,1,1-trichloroethane, trichloroethylene (TCE), tetrachloroethylene (PCE), chloroform and carbon tetrachloride.

Oxygenated Solvents: acetone, methyl ethyl ketone, butyl-cellosolve and various alcohols, ethers and amines.

Aromatic Hydrocarbon Solvents: benzene, toluene, ethyl benzene and xylene.

Fluorocarbons: freon.

Different solvents have different concerns for sewer disposal. Some solvents are not regulated at all. The criteria for regulating solvents for disposal will be discussed below.

CRITERIA FOR REGULATING SOLVENTS FOR SEWER DISPOSAL

Solvent-contaminated wastewater is regulated for sewer disposal for the following reasons:

1. to protect the sewer and the municipal wastewater treatment plant from physical damage, explosion hazard and excessive maintenance needs;
2. to protect the sewer workers and the plant personnel from occupational health hazards;
3. to limit the amount of toxic materials discharged to the air environment through aeration stripping at the wastewater treatment plant and to the receiving water environment through treatment plant pass-through;
4. to limit the amount of toxic accumulation in the sewage sludge to allow for sludge recycling as compost or disposal in municipal landfills; and

5. to limit the amount of toxic accumulation in the reclaimed wastewater to allow for recycling in groundwater recharge, landscape irrigation and various industrial uses.

It should be noted that a municipal sewer agency is itself under regulation by various Federal and State environmental and health agencies to achieve the above objectives in occupational and environmental health protection.

AREAS OF REGULATORY CONCERNS AND CORRESPONDING DISCHARGE LIMITS

1. Sewerage System Safety

Concerns: Explosive conditions in the sewer and treatment plant from solvent discharge

Limits: Lower explosive limit (LEL) of less than 20%

Requirements: Install combustible gas monitoring system if required (Please consult LACSD's Combustible Gas Monitoring System Guidelines)

2. Sewer Maintenance and Protection

Concerns: Excessive accumulation of oil and grease and acidic corrosion of sewers

Limits: Oil and grease limit of 75 mg/l for non-biodegradable organic compounds and pH greater than 6

Requirements: Clarifiers or treatment system to remove oil and grease; pH neutralization system and pH monitoring probe and recorder

3. Discharge to the Air Environment

Concerns: Volatilization of organics in the sewer and stripping of organics to the air in the aeration processes at the wastewater treatment plant that would affect both air quality (smog formulation) and human health

Limits: Compounds with extremely high toxicity and with extremely high volatility in the sewer, detection limit level, (for example, vinyl chloride = 15 ug/l)

Other compounds with known toxicities, total limit of all compounds under the EPA priority pollutant list not to exceed 1,000 ug/l [for example, summation of all chlorinated solvents (EPA Method 601) and aromatic solvents (EPA Method 602) not to exceed 1,000 ug/l]

Other biodegradable organic compounds, e.g. acetone, methyl ethyl ketone, no limits at this time (if these compounds were found to contribute to smog and the degradation of air quality, additional controls may be imposed)

Requirements: Waste minimization, good housekeeping and pretreatment of solvent-contaminated wastewater with various technologies, e.g. air stripping, activated carbon adsorption and U.V.-ozone destruction

4. Discharge to the Receiving Water/Groundwater Environment

Concerns: Pass-through of untreated toxic organics to the receiving water environment through treated wastewater discharges and to the groundwater environment through reclaimed water recharge

Limits: For organic compounds under the EPA priority pollutant list, total toxic organics limit of 1,000 ug/l

For organic compounds not on the lists that would pass through the treatment process, limits may be imposed on a case-by-case basis based on toxicity and other concerns

Requirements: Waste minimization, good housekeeping and pretreatment of wastewater, e.g. conventional oily wastewater treatment together with activated carbon adsorption and other polishing treatment methods

5. Accumulation in the Sewage Sludge

Concerns: Toxic organics removed in the sewage sludge at the wastewater treatment plant may limit the recycling of sludge as compost and may also limit the disposal of sludge in municipal landfills

Limits: No limits are imposed at this time since Federal and State regulations for sludge reuse as compost and for disposal in municipal landfills have not been issued

Requirements: Waste minimization, good housekeeping and pretreatment of wastewater as required

STRATEGY FOR SEWER DISPOSAL OF SOLVENT-CONTAMINATED WASTEWATER

1. Waste minimization

2. Solvent waste segregation
   - .Segregate the toxic and the nontoxic solvents
   - .Segregate the solvent wastewater from general industrial wastewater that may not need treatment

3. Conventional wastewater treatment

4. Toxic organics treatment
   - .Air stripping and incineration
   - .Activated carbon adsorption
   - .Other innovative treatment processes

PERMIT APPLICATION REQUIREMENTS FOR WASTEWATER TREATMENT SYSTEM

1. General statement on the goal of the treatment facility and the types of waste to be treated.

2. Wastewater quantity and quality characterization

   - .Quantity: average volume per day and peak volumes
   - .Quality: analysis for conventional and toxic organic pollutants (a complete screening test using EPA Test Methods 601, 602 or 624 and 625 may be required)

3. Wastewater Treatment System Plan

   - .Plot plan showing the plant sewers and the connection to the public sewer, the entry gate to the plant and the sampling point

   - .Treatment system schematic diagram and detailed engineering drawings with plan view and elevations, showing all unit processes, tanks, pipings, sumps, dikes, flow meter and monitoring devices and all sidestream management systems like sludge cake storage, vented gas suction and incineration, and oil skimming reclamation (Information on mass balance and design criteria are helpful.)

   - .All design and construction drawings to be prepared and signed by a California registered professional engineer.

   - .Equipment specification and ratings for major equipment and monitoring devices, including catalogue cuts or shop drawings

.Operation and Maintenance Manual, including operation, inspection and maintenance checklists and procedures, emergency trouble-shooting procedures and list of spare parts and chemicals to be stocked (Only an outline needs to be submitted with the application. The full manual is due on completion of construction.)

.Laboratory support, including analysis capability in-house, quality assurance program and a list of major instruments, and off-site backup.

.Discharge monitoring system, including (if required) open-channel flow meter and recorder, pH probe and recorder, other selective monitoring instruments as needed (For the flow monitoring system, please consult LACSD policy on flow monitoring.)

.Spillage management procedure (Please consult LACSD policy on spill containment)

.Proposed sludge disposal or stabilization locations

.Proposed solvent skimming reclamation, incineration or disposal locations, if needed

.Vented gas caustic scrubbing and/or incineration system, if required

4. Charges

Annual surcharge: charge based on wastewater flow and strength in terms of suspended solids and chemical oxidation demand (COD)

Connection fee: one-time sewer capacity fee based on the flow and strength of the wastewater

5. Additional Information Requirements for Groundwater Contamination Clean-up Permits

.The remedial action plan
.Detailed information of wellwater sampling and well pumping yield to characterize the wastewater quality and quantity

SUMMARY

1. Different solvent wastes have different concerns for sewer disposal
   .Flammability
   .Sewer maintenance
   .Toxicity to humans and the environment
   .Volatility and contribution to smog formation

2. Sewer discharge limits are as follows:
   - .Flammability: LEL <20%
   - .Sewer maintenance: oil and grease content <75 mg/l, pH >6
   - .Toxicity: TTO = 1,000 ug/l
   - .Volatility: none at present

3. Strategy for sewer disposal may be as follows:
   - .Waste segregation
   - .Conventional wastewater treatment
   - .toxic organics treatment

APPENDIX I

A CASE HISTORY OF TREATMENT OF SOLVENT-CONTAMINATED GROUNDWATER FOR SEWER DISPOSAL

BACKGROUND

Company A produces specialty chemical cleaning and stripping compounds. Large amounts of chlorinated and nonchlorinated solvents are used as raw materials and are also stored on-site. In 1983, the company conducted a voluntary environmental audit and detected the presence of organic solvents in shallow subsurface soil and groundwater around the chemical loading dock and underground tank farm areas. A remedial action plan was submitted to the California State Regional Water Quality Control Board to correct the contamination. A consulting engineer/hydrogeologist was hired to perform a site assessment. The maximum concentrations detected in groundwater were 30,000 mg/l for butyl cellosolve, 3,200 mg/l for kerosene, 1,700 mg/l for naphthalene, 1,400 mg/l for methyl ethyl ketone, 120 mg/l for acetone and less than 1 mg/l for other chlorinated solvents. Findings suggested that the spillage from tank overfilling was primarily the source of contamination. The consultant proposed to extract and treat the contaminated groundwater at a rate of 1,000 gallons per day from a drainage gallery and discharge it to the sewer. The treatment system was built and has been operating since early 1986.

DESCRIPTION OF THE TREATMENT SYSTEM

A schematic diagram of the treatment system is given in Figure 1. The major treatment processes are listed as follows:

.Flow equalization tank
.Cartridge filters to remove soil particles
.Fuel hydrocarbon pre-filter (Klensorb 100) to remove fuel hydrocarbons and prevent potential blinding of the downstream activated carbon system
.Dual bed granular activated carbon adsorption system for toxic organics removal
.Flow measurement system

TREATMENT RESULTS

The quality of the treated wastewater from the system has been excellent. The individual chlorinated solvent concentrations are down to 0.01 mg/l. The naphthalene concentration is also down. Butyl cellosolve is also incidentally removed, but acetone and MEK are not. Comparison of the influent and effluent concentrations over a period of six months is given in Table 1.

TABLE 1

COMPARISON OF INFLUENT AND EFFLUENT CONCENTRATIONS OF CONTAMINANTS TO THE TREATMENT SYSTEM

Contaminants (ug/l)	Max. Conc. in Monitoring Wells	TREATMENT SYSTEM PERFORMANCE					
		Influent 1/86	Effluent 1/86	Influent 3/86	Effluent 3/86	Influent 6/86	Effluent 6/86
Regulated							
methylene chloride	350	350	ND(5)	ND	ND	ND	ND
1,1-dichloroethane	1,100	10	ND(5)	100	10	50	20
1,2-trans-dichloroethene	500	10	ND(5)	30	ND	40	ND
1,1,1-trichloroethane	700	4,000	10	ND(5)	ND	ND	ND
trichloroethene	700	10	ND(5)	8	ND	ND	ND
naphthalene	1,700,000	--	--	1,600	ND(1,000)	1,300	ND(5)
toluene	370	70	65	ND(5)	ND	7	ND
Total Toxic Organics	1,703,350	4,450	75	1,738	10	1,397	20
Nonregulated							
acetone	120,000	1,800	1,500	2,400	2,200	170	500
2-butanone (MEK)	1,400,000	200,000	24,000	150	150	ND(5)	ND
2-hexanone	--	50	50	ND(5)	ND	ND	ND
total xylene	--	55	25	225	ND(5)	5	ND
butyl cellosolve	30,000,000	--	--	ND(5,000)	ND	2,880	832

*ND - not detected. Limit of detection appears in parenthesis

FIGURE 1

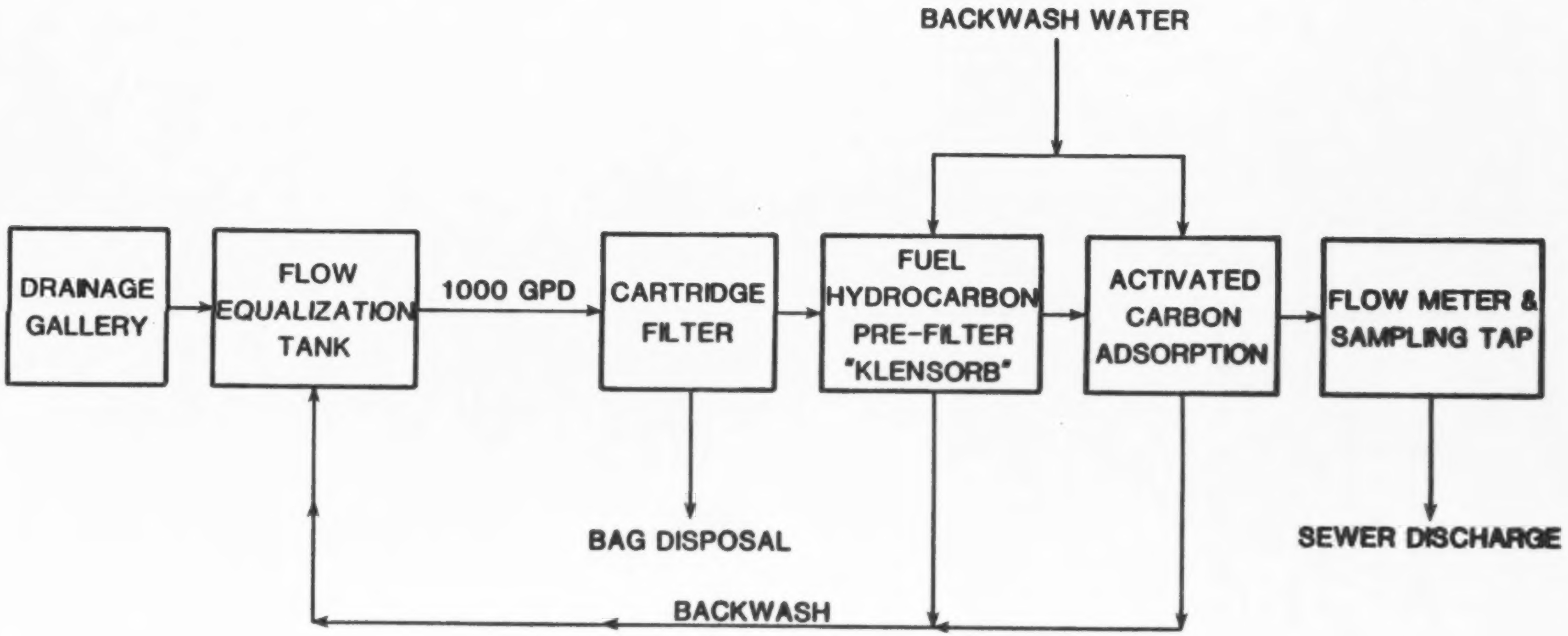
BACKWASH WATER
DRAINAGE GALLERY
FLOW EQUALIZATION TANK
1000 GPD
CARTRIDGE FILTER
FUEL HYDROCARBON PRE-FILTER "KLENSORB"
ACTIVATED CARBON ADSORPTION
FLOW METER & SAMPLING TAP
BAG DISPOSAL
SEWER DISCHARGE
BACKWASH

FIGURE 1 PROCESS FLOW DIAGRAM OF THE SOLVENT CONTAMINATED GROUNDWATER TREATMENT SYSTEM

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8 September 1986

Outline for presentation at the Solvent Waste Reduction Alternatives Symposium, October 20, 21, 23, 24. Presenter: E.L. Meyer, for Aerojet General Sacramento Environmental Operations

Subject: Waste Minimization and Alternative Technology.

I. Defining the Problem
    A. Solvent usage
    B. Problems from past practices

II. Regulatory Background
    A. Land disposal phase-out programs
        1. Department of Health Services
            a. Title 22 recycling requirements
            b. Restricted Wastes
            c. Proposed legislation
        2. Federal RCRA requirements
            a. Waste minimization
            b. Land disposal ban
    B. Requirements for treatment and recycling facilities
        1. Federal (RCRA)
        2. State (DHS, WQCB, ARB)
        3. Local

III. Recycling and Treatment technologies
    A. What Aerojet has done
        1. Chloroform recovery
        2. Trichloroethane recovery
        3. Ethylene dichloride recovery
    B. Other alternatives
        1. Off-site recycling
        2. Incineration
        3. Source Reduction
        4. Other Technologies

IV. Summary and Conclusions
    A. Current situation
    B. Future problems and opportunities

V. Questions and Answers

Presentation for the Solvent Waste Reduction Alternatives Symposia, October 20-21, 23-24, 1986.

Presenter: E.L. Meyer, for Aerojet General Sacramento Environmental Operations

Subject: Waste Minimization and Alternative Technology

I. Defining the Problem

A. Solvent Usage

Solvents are essential to American industry and business both large and small. Solvents are used to perform important roles such as cleaning, carriers for other materials in chemical manufacturing processes, as a carrier for the safe transportation of certain explosives, and diluting or thinning paints and other products.

B. Problems from Past Practices

Prior to passage of the Resource Conservation and Recovery Act in 1980, there were few controls on the management of spent solvents. Many solvents were in widespread use for years before scientific research disclosed their possible effects on human health. Potential pathways for water contamination were not understood by industry, management or the regulators. Consequently, many areas of the country are now undergoing cleanup operations as a result of past management practices.

II. Regulatory Background

A. Land Disposal Phase-out Programs

1. Department of Health Services

a. Title 22 Recycling Requirements

Article 12 of Title 22 lists spent solvents as recyclable hazardous wastes, under Section 66796. Suggested reclamation methods are rectification, ion exchange, adsorption or extraction. Combustible waste solvents can be burned as an energy source. If recyclable waste solvents are sent to an off-site disposal facility, DHS may and can require the generator to provide a written statement justifying why the waste was not recycled.

b. Restricted Wastes

Under Article 15 of Title 22, liquid wastes containing 1000 mg/kg or greater halogenated organic compounds have been banned from land disposal in California since 1 January 1985. Organic sludges and solids containing 1000 mg/kg or greater halogenated organic compounds will be banned from land disposal in California on 8 July 1987. Lab packs containing restricted solvents will also be banned from land disposal.

c. Proposed Legislation

The Governor's Task Force on Toxics, Waste and Technology final report issued in May 1986 calls for establishment of "residuals repositories" and prohibition of land disposal of all untreated hazardous wastes by 1995. Legislation will be written over the next few years to carry out the goals of the Task Force.

2. Federal RCRA Requirements

a. Waste Minimization

The November 1984 RCRA amendments require all hazardous waste generators to establish waste minimization programs. Since 1 September 1985, generators have been required to sign a certification on manifests for off-site shipment stating that they have a program in place to reduce the volume or quantity and toxicity of the waste generated, and that the waste management method minimizes the threat to human health and the environment. Generators are also required to submit reports every two years describing waste minimization efforts and actual reductions in waste volume and toxicity. These requirements are found in Section 3002 of RCRA. In Section 8004(r), EPA was required to report to Congress by 1 October 1986 recommendations for further waste minimization requirements.

b. Land Disposal Ban

On 14 January 1986, EPA proposed regulations to restrict the land disposal of solvents. EPA plans to ban the land disposal of most solvents, effective 8 November 1986, unless treatment levels (2 ppm for most constituents) are met. Very dilute wastewaters containing solvents and having 1% or less total organic constituents are prohibited from land disposal on 8 November 1988.

B. Requirements for Treatment and Recycling Facilities

1. Federal (RCRA)

EPA issued new RCRA recycling regulations on 4 January 1985 that define what types of materials are considered solid waste or hazardous waste when recycled by various methods. These requirements have been incorporated in 40 CFR 260 through 266. Some types of on-site, closed-loop recycling are exempt from RCRA permitting. On-site waste treatment prior to off-site shipment requires a RCRA permit.

2. State (DHS, WRCB, ARB)

Operators of off-site Resource Recovery Facilities are subject to most of the same requirements as hazardous waste treatment, storage and disposal facilities. Under Title 22, Article 12, series A,B and C permits may be issued to off-site recycling facilities, depending on the type of waste received and how it is managed. Treatment prior to off-site shipment or discharge to sewer requires a hazardous waste facility permit from the Department of Health Services, with Water Quality Control Board approval. Some types of on-site recycling are exempt. An example is recycling spent solvent on-site, then reusing the recycled solvent back in the process. The Air Resources Board is in the process of designating many solvents as Toxic Air Contaminants and establishing suggested control measures.

3. Local

Any discharge of treated waste to sewer will require a permit from the local Publicly Owned Treatment Works. Air Pollution Control Districts or Air Quality Management Districts will require permits for emissions from treatment and recycling units, and may set control requirements for Toxic Air Contaminants. Local zoning, land use, fire code, and community right-to-know requirements must also be determined.

III. Recycling and Treatment Technologies

A. What Aerojet has Done

1. Chloroform Recovery

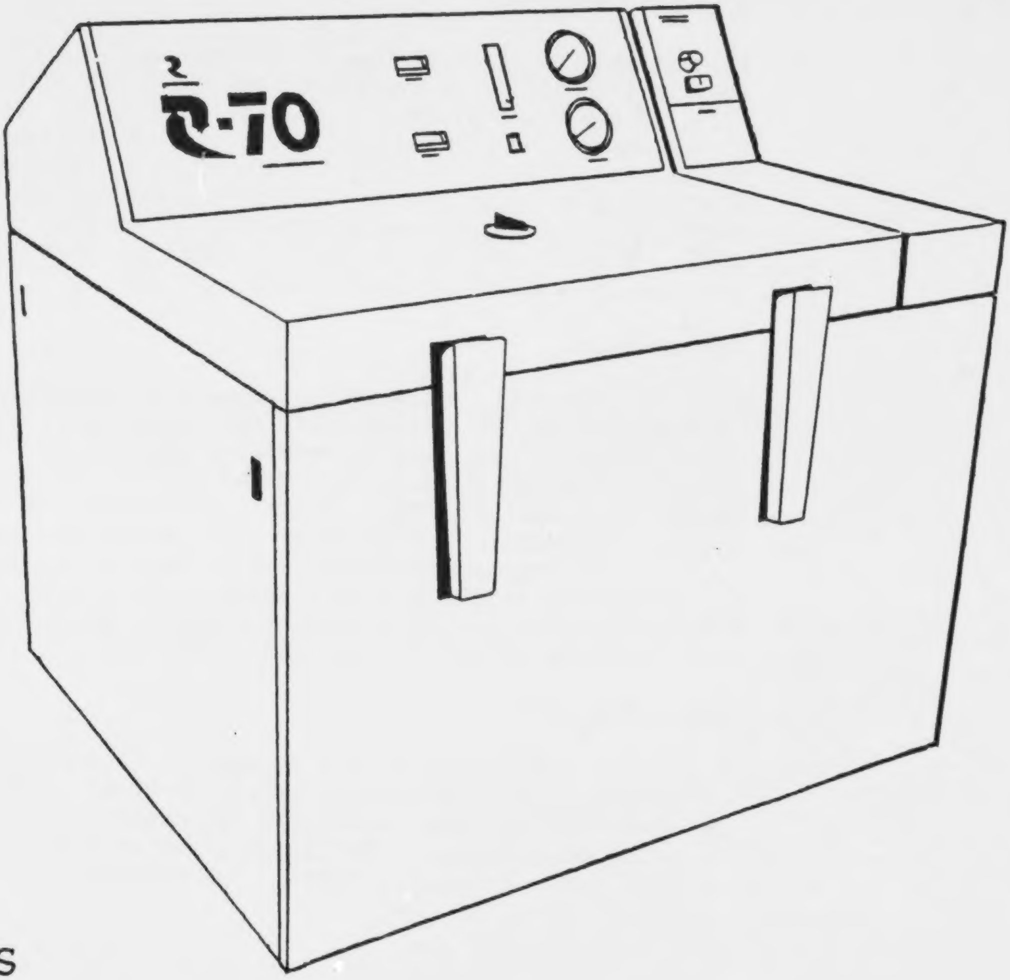
A carbon adsorption system is used to recover chloroform from the waste stream of the process which produces a fungicide, OBPA, (10,10-oxybisphenoxarsine). A filter is used to remove particulates from the waste stream and a "guard bed" of carbon is used to remove heavy organic contaminants. The adsorption system utilizes two parrallel carbon beds which are used alternately. Changeover from one bed to the other can be triggered by bed saturation, which is measured by infrared analysis of the exhaust, or by a back-up timer. During desorption, the chloroform is steam stripped from the carbon and the steam/chloroform mixture is condensed and separated by decanting. The water phase is further stripped of dissolved chloroform in a desorber column. During the drying phase of the regeneration cycle, warm, filtered air is blown through the carbon beds to remove excess moisture. Approximately 1800 lbs. of chloroform per day are vented into the carbon adsorption system, which operates at about 95-98% efficiency. The recovered chloroform is reused in the manufacturing process. Chloroform emissions to the atmosphere is reduced from about 1400 lbs./day to 33-65 lbs./day. Installation costs for this unit was $350K with an estimated 2 to 3 years payback on investment.

2. Trichloroethane Recovery

a) A commercial solvent recovery still is used to reclaim waste 1,1,1-trichloroethane that is contaminated with solid rocket propellant. The waste solvent is filtered to remove particulates greater than 10 microns, and then stored in the feed tank for the still. The solvent is fed into the Recyclene R-70 reclaimer unit. The electrically heated boiler tank heats a silicone oil, which in turn heats and evaporates the solvent. The solvent vapor is condensed by countercurrent chilled water and collected in an integral condensate storage tank. The reclaimed solvent is pumped into a 55-gallon drum for subsequent reuse in general cleaning operations. Three 35-gallon batches of propellant-contaminated solvent can be processed weekly. Total emissions from the system to the atmosphere are estimated at 8 lbs./day. This operation is done remotely as the residue from this process is sensitive and ignitable. The residue is packaged and treated prior to off-site disposal. This unit was purchased from Zerpa Industries of San Jose, California.

b) A Westates Series WSA, model H-1.5-1.5 carbon adsorber is used to recover 1,1,1-trichloroethane which has been used to dissolve the styrofoam core of a Polaris motor. Approximately 65 gallons of solvent are used per motor. The adsorber contains thirteen 24" X 24" X 3/4" carbon filters. The filters are changed weekly, or after 2 Polaris cores have been processed. Initial tests indicated for 701 pounds of solvent introduced into the system, 7.3 pounds escaped to the atmosphere for a recovery rate of 98.96 percent. The recovered solvent is packaged and sent to an off-site recycler.

RECYCLENE
R-70
MANUAL



ERPA INDUSTRIES
1 TRADE ZONE BLVD.,
JOSE, CA. 95131

90

3. Ethylene Dichloride Recovery

Ethylene dichloride from the nitroplasticizer production process is collected in a holding tank. The solvent is adsorbed on one of two parallel carbon beds. The solvent is distilled, condensed, and then collected in a vacuum receiver. Approximately 1000 lbs. EDC per day are vented into the carbon adsorption system, which operates at about 95-98% efficiency. The recovered solvent is returned to the process. The column bottoms are transferred to the waste holding tank for disposal.

B. Other Alternatives

1. Off-site Recycling

Aerojet shipped about 61 tons of solvent waste to off-site recyclers in 1985. We use Romic Chemical Company of East Palo Alto, Bayday Chemical Company of Santa Clara, and Ultra-Chem of San Jose. The EPA Hazardous Waste Treatment Directory and the California Waste Exchange Directory, and other commercial directories are available to assist in locating recycling facilities. We inspect Recycle Facilities as well as all other TSD Facilities before authorization is given for the operating organizations to use their services.

2. Incineration

There are currently no permitted commercial hazardous waste incinerators in California. Only four have been permitted in other states by EPA. DHS is reviewing applications for commercial incinerators in Carson and Vernon, California. Aerojet does not currently utilize incineration for solvent wastes. The feasibility of an on-site incinerator is being studied. An estimated five million dollars is needed for an incinerator to handle Aerojet's major waste streams. A treatment system for all energetic material would increase this figure to as much as ten million dollars.

3. Source Reduction

a) Aerojet has installed heat exchangers to cool wastewater in the 1,3,5-trimino-2,4,6-trinitrobenzene (TATB) production process, decreasing the amount of toluene dissolved in water. The amount of water used in product wash cycles was also reduced. Approximately 2,000 gallons of water were saved and 8 gallons of toluene recovered per day of operation. This amounts to a seven million gallon reduction per year. The recovered toluene is sent to an off-site recycler.

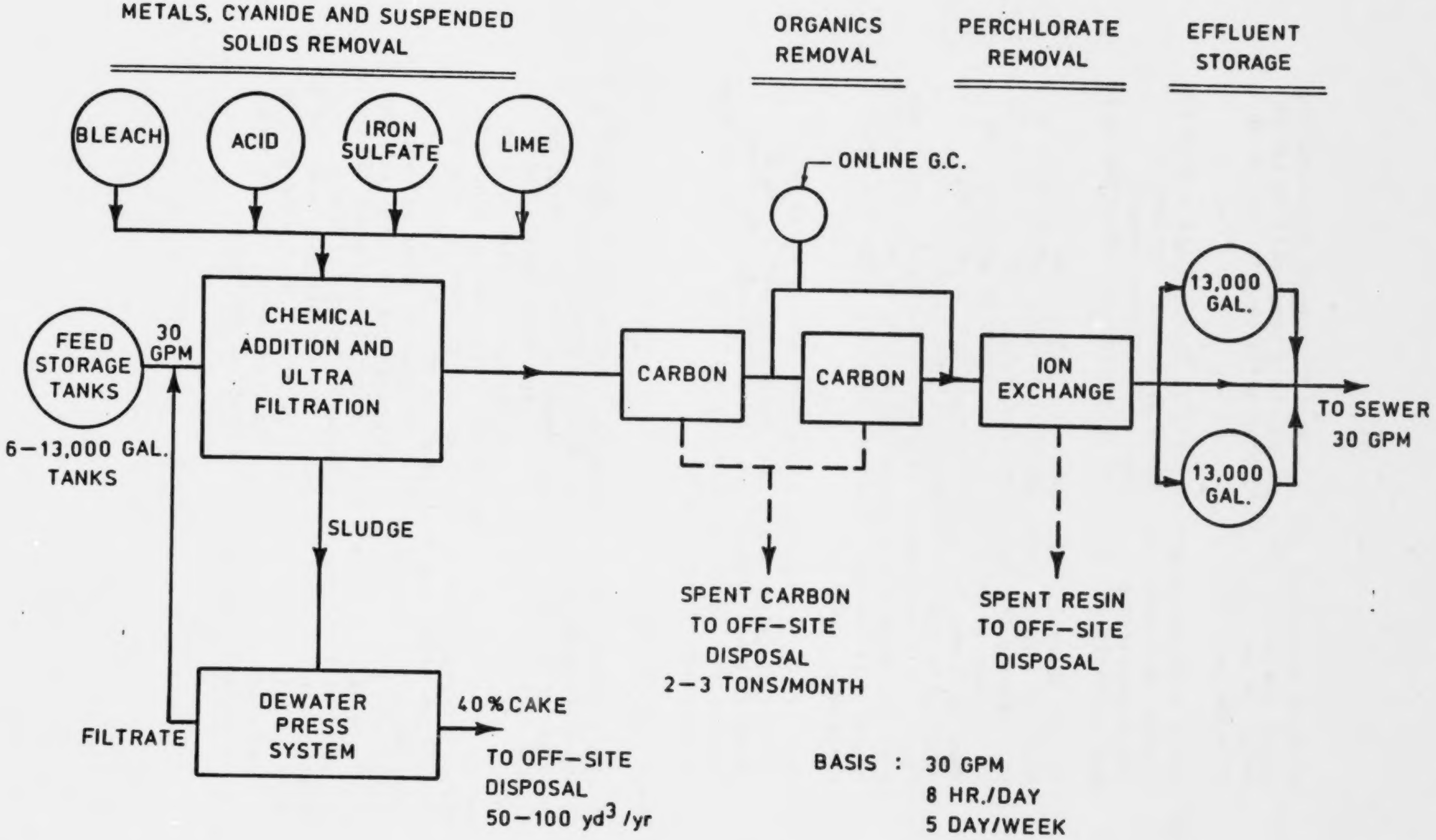
b) The chloroform content of the XIII Diisocyanate production process wastewater was reduced by a more efficient air sparging system and procedure. The system removes approximately 1/2 gallon of chloroform per operating day.

c) Aerojet General Sacramento Environmental Operations is drafting a Waste Minimization Administrative Standard that will require the operations at the Sacramento Facility to be reviewed to determine source reduction and recycling opportunities. The operating organizations will be required to set goals and report results on an annual basis. This requirement will ensure Aerojet's compliance with the waste minimization regulations as well as provide needed data for the annual and bi-enniel hazardous waste management reports.

d) Part of every hazardous waste management program is a waste segregation plan. The indiscriminant mixing of waste solvents disqualifies the material for recycling. Aerojet is constantly reviewing work areas for better ways to segregate waste streams.

4. Other Technologies

Aerojet's Central Waste Management organization is designing a dilute waste treatment system which is planned for installation in 1987. Dilute solvent wastes will first be treated in an ultrafiltration unit to remove metals and solids. The waste will then pass through 2 carbon beds in series. The unit will treat about 30 gallons per minute of waste, 8 hours per day. About 200,000 gallons per year of 400-500 ppm methylene chloride waste will be treated. Approximately 1,800,000 gallons per year of other solvent wastes will be treated, including trichloroethylene (<10 ppm), dichloroethane (<10 ppm), and trichloroethane (about 150 ppm). The waste will be reduced to 4 ppm or less total toxic organics for discharge to sewer. The recovered solvent can be reused. Only virgin carbon will be used. The carbon will be changed every 15,000 gallons. The used carbon will be sent to Calgon in Pennsylvania for regeneration and reuse.


METALS, CYANIDE AND SUSPENDED SOLIDS REMOVAL
ORGANICS REMOVAL
PERCHLORATE REMOVAL
EFFLUENT STORAGE
BLEACH
ACID
IRON SULFATE
LIME
ONLINE G.C.
FEED STORAGE TANKS
30 GPM
6–13,000 GAL. TANKS
CHEMICAL ADDITION AND ULTRA FILTRATION
CARBON
CARBON
ION EXCHANGE
13,000 GAL.
13,000 GAL.
TO SEWER 30 GPM
SLUDGE
SPENT CARBON TO OFF–SITE DISPOSAL 2–3 TONS/MONTH
SPENT RESIN TO OFF–SITE DISPOSAL
FILTRATE
DEWATER PRESS SYSTEM
40% CAKE
TO OFF–SITE DISPOSAL 50–100 yd³ /yr
BASIS : 30 GPM
8 HR./DAY
5 DAY/WEEK

DILUTE HAZARDOUS WASTE TREATMENT PLANT

(PROPOSED)

IV. Summary and Conclusions

A. Current Situation

Aerojet has made much progress in recovering and recycling waste solvents, but more work remains to be done. Some solvent wastes are going to land disposal at this time, such as still bottoms, paint waste, solvent/oil mixtures, and spent carbon.

B. Future Problems and Opportunities

Some problems that have arisen with existing solvent recovery systems have been: interference of contaminants with the carbon bed, including coating or breakdown of carbon particles and saturation of the bed; incompatability of solvents and contaminants with initial recovery system materials; and reduction of carbon adsorption efficiency when humidity is high. The dilute system needs to be constructed and put into operation. Alternatives need to be identified for remaining solvent wastes. Industry and regulators need to work together on incinerator siting.

Hazardous Solvent Wastes Can be Reduced

by

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Hardly a day goes by without the news containing another story about some unsuspecting community being thrust into a hazardous waste issue. Some stories are about towns victimized by transportation or plant accidents. Others tell of the discovery of abandoned reservoirs of wastes at former plants or disposal sites. Still others concern localities that have been chosen for hazardous waste treatment or disposal facilities. These stories, as well as recent action by Congress on Superfund legislation, underscore the fact that hazardous wastes are an issue that is gripping the nation.

The almost universal consensus is that the best way to manage hazardous wastes in the future is to reduce them. Everyone, from the Chemical Manufacturers Association, which refers to waste reduction as the "optimal strategy", to numerous governmental agencies to environmental groups, supports the concept of source reduction as the preferred means of coping with hazardous wastes. Although widely endorsed, there has been very little study of the extent to which hazardous waste reduction is being employed and the factors influencing its use.

Today,I would like to briefly describe the results of three years of research that INFORM conducted between 1982-85 on the extent of hazardous waste reduction in the organic chemical industry and the factors encouraging and discouraging action to avoid the generation of wastes at the source. Finally, I would like to share with you some thoughts on initiatives that can be undertaken to help hazardous waste reduction reach its full potential. Although our study did not focus exclusively on organic solvents, they did represent a majority of the hazardous wastes reported at the twenty-nine plants studied and our findings are certainly applicable to your industry.

INFORM is a non-profit research organization with headquarters in New York City. INFORM is devoted to research and education on major natural resource policy issues. INFORM is special in its emphasis on case-study research.

This hazardous waste reduction study is in keeping with INFORM's tradition. During the research portion of this study, we took a very close look at twenty-nine different organic chemical plants located in New Jersey, Ohio, or California, states with quite different state programs. These twenty-nine plants were selected to be as representative as possible of the very diverse segment of our economy known as the "organic chemical industry". We studied small, medium, and large plants ranging from less than a handful of employees to the duPont Deepwater, N.J. plant employing over 4000. The plants also vary widely in the products that they make, the processes that they employ, and the markets that they seek. Some of our plants, such as Scher Chemical, are family operated; others are plants of large publicly owned firms better known for other products (e.g. steel--USX, dairy products--Borden, or paint--Sherwin-Williams); one, Rhone-Polenc, is owned by French government. However, none of the plants were chosen on the basis of any foreknowledge of their environmental or waste reduction history, good or bad. Thus, although a limited sample, we feel they provide valuable insights into what is actually happening at organic chemical plants around the country.

The organic chemical industry was chosen for this study because it is reported by EPA to be the sector responsible for producing more hazardous wastes than any other in our economy. Moreover, its production has been increasing far faster than our economy has been growing since World War II.

Our definition of "hazardous waste" differs from that used in various environmental laws because it refers to all toxic chemicals produced, irrespective of whether they may become solid wastes or air or water pollutants. We also set our own definition of the term "hazardous waste reduction". Instead of its frequent use in regulations to refer to actions to avoid landfilling chemicals, our definition refers strictly to actions taken to prevent the production of hazardous wastes at their sources, so that they will not exist to enter our air, water, or landfills.

What did we learn, after three years spent examining these twenty-nine chemical plants? Let me sum up our three major findings:

First, and possibly foremost, we learned that efforts to reduce hazardous wastes can, and sometimes do, achieve impressive results, both in terms of environmental benefits and in terms of dollar savings for the companies involved. Of our twenty-nine study plants, twelve reported taking steps that significantly reduced the generation of particular waste streams. Some of the changes they made were remarkably effective and at the same time simple, straightforward and inexpensive.

For example, in New Jersey, four out of the eleven companies studied (Exxon, CIBA-GEIGY, Atlantic Industries and Merck) reduced their output of wastes by over four million pounds per year with savings of hundreds of thousands of dollars in lower raw material costs, and lower waste management costs. These reductions involved such hazardous organic solvents as methylene chloride, nitrobenzene, and methyl ethyl ketone, as well as many other hazardous substances.

Our second major finding was that, despite the kinds of benefits companies could reap from waste reduction, and despite all the talk about the critical importance of this strategy by those in and outside the industry, waste reduction initiatives were being applied to only a tiny fraction of the total wastes generated by the twenty-nine plants that we studied. Where one waste stream was reduced, dozens or hundreds of other chemical waste streams were not. Further, in most of the fourty-four individual waste reduction projects actually identified at twelve of our study plants, we found that companies took action only when their backs were to the wall. That is, they acted when the more common waste treatment and disposal methods on which they usually relied were inadequate, due to regulatory or economic considerations. Not one plant that we looked at was methodically assessing its entire operations with the aim of achieving overall waste reduction.

Our third major finding was that environmental regulations at the federal and state levels were failing to provide consistent incentives for companies to reduce their wastes. Very few regulations call directly for waste reduction, and the regulations restricting other disposal options have forced very few companies to turn seriously to this alternative. Because so few toxic substances are actually regulated across the board, companies have a good deal of room to discharge hazardous wastes from stacks and outfall pipes in an uncontrolled manner. Of the thousands of potentially threatening chemicals now in routine use, EPA regulates only six as hazardous air pollutants and 126 as water pollutants, while it regulates over 300 as solid wastes. Some states have taken the initiative to go a little further. We found, for example, that California has set air emission standards for nine toxic chemicals and New Jersey has set them for eleven.

Several specific exemptions and loopholes in the few federal and state laws that do exist in this area have kept open some cheap and easy-to-use waste disposal options that have made the search for waste reduction possibilities less vital. One has been the exemption under the Resource Conservation and Recovery Act (RCRA) that allows companies to burn hazardous wastes as fuels, without the stringent controls that would be required if these same wastes were simply being burned for disposal. This exemption, established in 1976 when concerns about energy supplies and the search for fuels other than foreign oil was most intense, now actually encourages the generation of toxic waste. Another example is the loophole which allows the use of deepwells for disposal of hazardous wastes, which has made this inexpensive disposal option so widely popular. A third avenue for inexpensive disposal of hazardous wastes lies in the inadequate implementation of sewage treatment plant "pretreatment programs", under which sewage treatment plants are supposed to screen and regulate toxic discharges.

The three major findings I have just touched upon are discussed in INFORM's report Cutting Chemical Wastes, which was released in January. I would like to briefly describe three of the twenty-nine cases presented in the report that show in particularly graphic terms the types of exciting results that waste reduction can produce. These examples all involve organic solvents. These cases also show how relatively simple and inexpensive many of these waste reducing actions can be.

I'll begin by looking at the Exxon Chemical plant in Linden, New Jersey. This large plant, making lubricants and solvents, curbed its toxic air emissions of organic solvents dramatically, by 90 per cent! It reduced these emissions simply by installing equipment called "floating roofs" atop sixteen of the 200 tanks in which it stores large volumes of its solvents. Floating roofs are mechanical roofs that rest right on the roof surface of the liquid. They rise and fall as the level of the liquid rises and falls, and so prevent losses from evaporation.

There is nothing new about floating roofs. However, Exxon did not take advantage of this waste reduction strategy until it was required to do so by a specific government regulation, in this case, the State of New Jersey's air pollution regulations. (This requirement, by the way, was the only regulatory measure we found in our study that directly mandates waste reduction.) Much to Exxon's surprise, after installing the roofs, plant officials discovered they were saving so much money -- over $200,000 a year -- by not losing large volumes of raw material, that they installed additional floating roofs not required by the regulations.

Second, at its Pittsburg, California plant, Dow Chemical was able to eliminate entirely its hazardous air emissions from transfers of solvents and other liquid chemicals by replacing a pressurized technique with simple pumps.

Third, returning to the Linden, N.J. plant, Exxon was able to reduce the loading of organic wastes to its waste water by 75 per cent through a plant-wide program to identify the activities that were generating the wastes. Once identified, the plant was able to institute straight-forward and highly economical operational changes to reduce the wastes.

There are many opportunities for waste reduction just waiting to be discovered and implemented in the chemical and other industries. However, there is an urgent need for both economic incentives and new government and corporate attitudes, if the pace of waste reduction is to be accelerated.

I am happy to report that the federal government is now paying some attention to waste reduction -- however tentatively. Two substantive provisions in the 1984 RCRA amendments may promote waste reduction. These will restrict use of deepwells and more stringently control burning of toxic wastes as fuel. In addition, the 1984 amendments will require companies to at least think about waste reduction. Companies must sign a statement affirming that they have done "everything practicable" to minimize their wastes each time that they file manifests to ship wastes off-site and when they file bi-annual on-site waste reports. This provision, I repeat, will make companies think, but I want to reiterate that it does not make them act. The RCRA amendments also require EPA to explore technological and policy options for accelerating waste reduction by industry and to report its findings this October to Congress.

Government could surely do a lot more. Let me review for you some of the key measures that could be used to advance hazardous waste reduction. I hope that you will consider each one carefully. Federal and state governments could spur waste reduction in at least six ways:

1. Government could set more comprehensive standards for chemicals discharged to air, water and land resources.

2. Government needs to focus more attention on foreclosing cheap waste treatment and disposal methods for all types of wastes, not just landfilled wastes. Companies will then be forced to look for ways to reduce wastes rather than seeking to dispose of them through the least regulated routes.

3. Government could use more positive incentives to encourage business initiatives, such as offering informational and technical assistance. Ten to fifteen states have begun to move in this direction. North Carolina and Tennessee, for example, have established clearinghouses of information on waste reduction as an aid to industry. They give awards to companies that have been creative in this area and hold conferences to highlight the topic. North Carolina and Minnesota are among states now providing companies with technical help. Minnesota's "TAP" (Technical Assistance Program), which has been particularly visible, provides graduate chemical engineering students as consultants to companies (mostly small and medium-sized) which lack in-house expertise.

4. Government could use financial incentives to motivate waste reduction. Government could create a wholly different type of financial incentive in the form of taxes on total plant wastes. Such taxes exist nowhere at present. Several states, including Kentucky and Minnesota, have waste end taxes, but these apply only to solid wastes. To create such a tax, however, it is essential to have full information on the total discharges of individual plants, including discharges to air, water, sewage treatment plants, landfills, etc. Such information is not now available under virtually any state law, except for New Jersey. However, amendments that are now part of both the Senate and House Superfund bills pending in Congress would call for such complete information. Another financial incentive would be for states to offer tax credits and exemptions, as well as low-cost loans, to stimulate waste reduction. Presently, California, Illinois and New York are following this route.

5. State regulators could require waste generators to conduct overall waste reduction feasibility studies for their plants and evaluate the costs of reducing particular chemical wastes, or total toxic wastes, by a certain amount -- say 10, or 20 per cent -- over a given time period. Such reports could be a basic requirement in applying for discharge permits. This would certainly turn corporate attention in the crucial direction of waste reduction at its source. Communities could also pass ordinances doing the same thing.

6. Finally, regulators might create some kind of overall toxic permit for individual chemicals, instead of, or in addition to, the separate permits now used for air, water and solid waste discharges. If toluene, benzene and other hazardous organic solvents were regulated in this way, a strong incentive to reduce total discharges would exist.

I am going to end my talk today by emphasizing some steps that corporations could take on their own to advance waste reduction. It is certainly our conclusion at INFORM, after three years of studying the organic chemical industry, that more than adequate reasons exist for companies to move vigorously ahead for their own benefit. So much could be gained. They could reduce their regulatory problems related to pollution control, and achieve important, and in some cases, dramatic cost savings at the same time. They could also acquire a better corporate public image, while making their plant operations more efficient, and they could reduce their risks of liability, which chemical company managers fear more and more. What will it take for companies to move into the lead here? We have five suggestions:

1. Top corporate managers must become more aware and convinced of the many potential advantages that they may derive from waste reductions. The case studies in INFORM's report, we hope, will play an important role in increasing this awareness.

2. Companies need to implement information systems on the plant level that track the movement of hazardous substances. The type of waste audit systems we have in mind would identify individual chemicals entering the plants, indicating how much of each chemical is discharged as waste and into what environmental media. This would consequently identify how much of each chemical is being lost and where.

3. Companies need to establish accounting systems that will allow them to quantify all raw material, handling and disposal costs and will allow them to define the savings to be made by investments in waste reduction strategies of various kinds.

4. Companies need to develop a top management focus on waste reduction. This may well be accomplished by appointing a vice president directly responsible for waste reduction company-wide. This official would be the one to oversee shaping the kinds of information and accounting systems described above.

5. Companies need to create specific incentives which motivate plant managers to aggressively look for waste reduction opportunities and document the results, for example, bonuses given for specific waste reductions achieved.

I want to underline here the fact that not one of the twenty-nine companies that INFORM studied had the full combination of all the characteristics I am referring to: the information and accounting systems, the top management coordination, and the plant incentives. Instead, corporate information systems as well as pollution control priorities are being predominantly set in response to particular pressures by government agencies with a narrow end-of-the-pipe view of pollution control.

We can certainly all agree that preventing formation of harmful wastes is an obvious, and well as an essential, strategy for dealing with the devastating hazardous pollution problems we face in this country today and that we risk leaving as a heritage for future generations. However, let me repeat in closing that INFORM's research reveals the dismal fact that implementation of this strategy has barely begun. A great deal needs to be done to promote changes in attitudes, as well as practices, to turn waste reduction from a compelling idea into a reality.

SOLVENT WASTE MANAGEMENT
AT
NORTHROP CORPORATION - ADVANCED SYSTEMS DIVISION

Prepared by:

WALTER J. MUNDY, MANAGER
FACILITIES & ENVIRONMENTAL PLANNING
10 SEPTEMBER 1986

HAZARDOUS WASTE MANAGEMENT...
HAZARDOUS WASTE AVOIDANCE...
HAZARDOUS WASTE MINIMIZATION...
HAZARDOUS WASTE REDUCTION...

These are all becoming common every day use terms!
They all apply to waste solvent.

At Northrop's Advanced Systems Division we have an aggressive Hazardous Waste Management Program that addresses Avoidance, Minimization and Reduction.

Let me define what these terms mean at Northrop with respect specifically to Solvents.

Avoidance

The management of those actions that eliminates the present or future need.

Minimization

The management of those actions that reduces the present or future need.

Reduction

The management of those actions that diminishes existing inventories.

Why is it necessary to consider these alternatives for solvent waste?

There are economic and regulation incentives for considering alternatives to the direct land disposal of solvent bearing hazardous waste.

The economic incentives for the avoidance minimization and reduction of solvent waste are two fold: first the savings in the initial cost and secondly, the savings in disposal cost. I might add a third, more nebulous, incentive... The cost of possible future environmental impairment liability.

The first chart (Figure 1) I will show the Flow of Hazardous Materials within the operating division from acquisition to disposal.

Our solvent waste avoidance, minimization reduction program is one hazardous material of many that follows the path illustrated.

You will note that our waste avoidance/minimization program is monitored by a Division Hazardous Materials Control Committee. As chairman of that committee I have committee representation from all of the functions that come in contact with hazardous materials.

A year and a half ago we were solidifying and landfill disposing of forty tons/year of organic and aqueous solvents and sludge wastes. This year we are recovering and recycling 99% of our solvent waste, utilizing on-site and off-site recycling facilities. Recovery and recycling contractors pick up, recover and recycle organic solvents, aqueous solvents and incinerate the sludges. (treated residuals) We also have a solvent recovery still on site to support pretreatment of proprietary coatings.

Waste Solvent Characterization

In November 1984 Congress amended the Resource Conservation and Recovery Act (RCRA) to restrict the land disposal of a number of hazardous wastes.

The first two wastes scheduled to be banned in November 1986 are Dioxin and solvent wastes.

The 1984 RCRA amendments specify five categories of solvent wastes which are banned from land disposal. They are:

F-001	Spent halogenated solvents used in degreasing: (Carbon tet.) (111 trichlorethylene)
F-002	Spent Halogenated Solvents
F-003	Spent Non-Halogenated Solvents (Xylene, acetone)
F-004	Spent Non-Halogenated Solvents (Cresols)
F-005	Spent Non-Halogenated Solvents (Toluene, MEK)

Category F-001, F-002, F-004 and F-005 are listed because they are all toxic. Category F-003 is listed because they are ignitable and are already banned from land disposal.

Following the EPA Characterizations, Aerospace solvents are characterized as toxic or ignitable for the purpose of disposal. Our goal is to eliminate landfill disposal of hazardous waste, except treated residuals and untreatable waste by the end of 1989.

Waste Stream Identification

Within our division operations we have 35 waste stream sources (users) identified. Of these 21 are generators of solvent waste. The solvent wastes we handle are generated from:

- o Wipe down cleaning operations
- o Coating thinners and clean up solvents from coating operations
- o Adhesive bonding solvent from composite fabrication

Waste Stream Identification (Continued)

- Degreaser solvents from processing operations
- Film processing developers from Photo and QA laboratories.

Waste Management Alternatives

There are four principal alternatives available as opposed to land disposal of solvent wastes. They are:

1. Destructive treatment including thermal oxidation (incineration)
2. Removal of toxic or ignitable constituents (total treatment prior to landfill)
3. Recovery, recycle and reuse or as a fuel substitute
4. Avoidance or elimination.

On-Site and Off-Site Treatment/Disposal

The majority of our solvent waste is covered under alternative No. 3 above and is recovered and recycled at an off-site contractor facility. Solvents are blended and treated and either recycled or used as an alternate fuel in a kiln. Sludges and hazardous solids are incinerated and residuals are land disposed.

We have a solvent recovery system and a silver recovery system to recover and treat photo processing chemicals. These are small units primarily used as a back up and to support Research and Development Laboratory quantities of these materials.

Summary of Solvent Waste Management Program

The following charts (Figures 2, 3 and 4) show the quantity increase and disposal activity at Advanced Systems Division since 1984. These charts clearly illustrate the success of our Hazardous Waste Minimization Program initiated in 1985. We are well ahead of our division and corporate goal.

Although this is but a drop in the bucket compared to the some three to four billion gallons of solvent waste generated in the United States and over one billion gallons that will be covered by proposed landfill restrictions, these solvents represent approximately 60% of our total hazardous waste volume at our Division and represents 12% of Northrop Southern California operations.

FIGURE 1

NORTHROP CORPORATION-ADVANCED SYSTEMS DIVISION

HAZARDOUS MATERIAL FLOW CHART

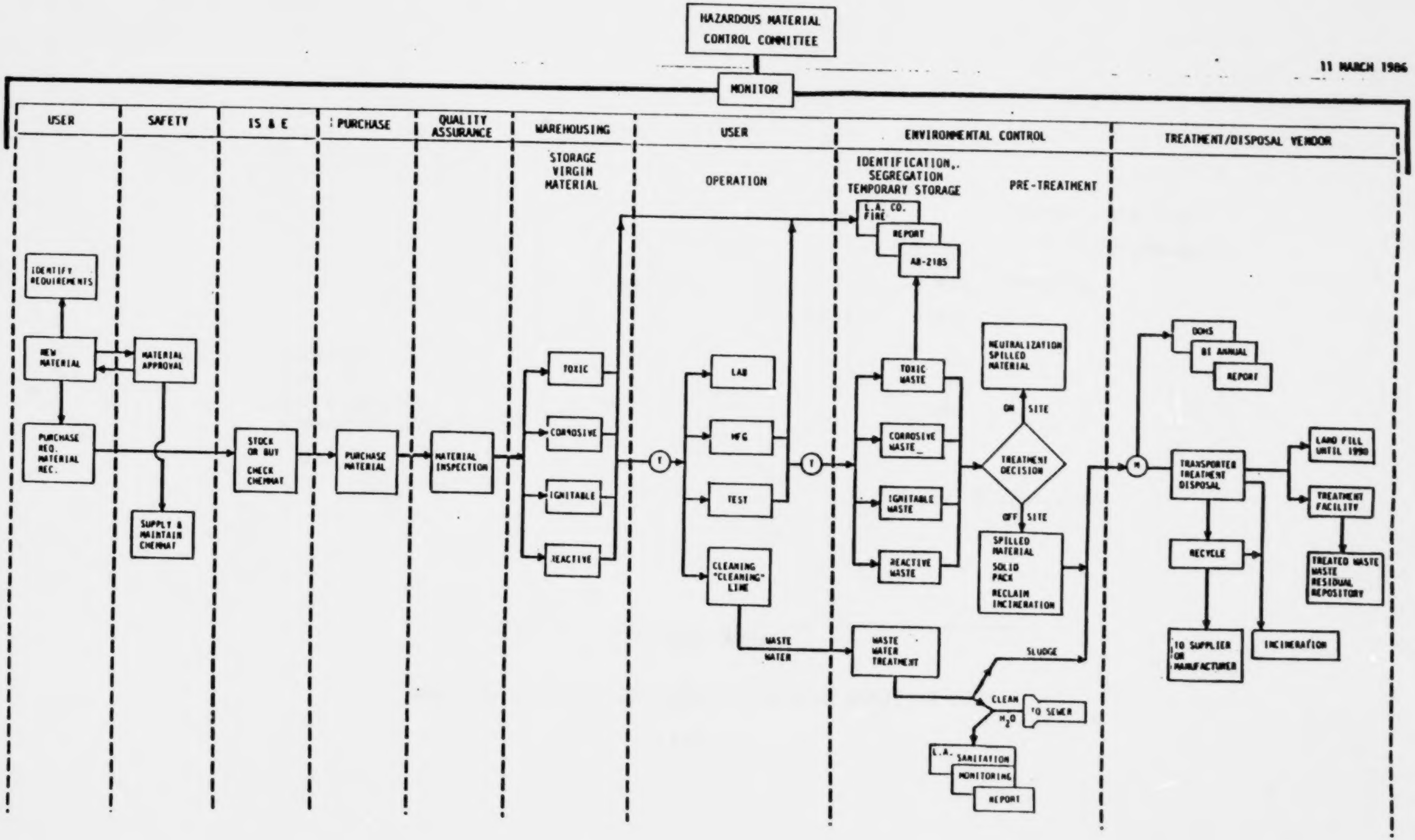
HAZARDOUS MATERIAL CONTROL COMMITTEE
MONITOR
11 MARCH 1986
USER
SAFETY
IS & E
PURCHASE
QUALITY ASSURANCE
WAREHOUSING
USER
ENVIRONMENTAL CONTROL
TREATMENT/DISPOSAL VENDOR
STORAGE VIRGIN MATERIAL
OPERATION
IDENTIFICATION, SEGREGATION TEMPORARY STORAGE
PRE-TREATMENT
IDENTIFY REQUIREMENTS
NEW MATERIAL
MATERIAL APPROVAL
PURCHASE REQ. MATERIAL REC.
SUPPLY & MAINTAIN CHEMMAT
STOCK OR BUY CHECK CHEMMAT
PURCHASE MATERIAL
MATERIAL INSPECTION
TOXIC
CORROSIVE
IGNITABLE
REACTIVE
T
LAB
MFG
TEST
CLEANING "CLEANING" LINE
T
WASTE WATER
L.A. CO. FIRE
REPORT
AB-2185
TOXIC WASTE
CORROSIVE WASTE
IGNITABLE WASTE
REACTIVE WASTE
WASTE WATER TREATMENT
NEUTRALIZATION SPILLED MATERIAL
ON SITE
TREATMENT DECISION
OFF SITE
SPILLED MATERIAL SOLID PACK RECLAIM INCINERATION
SLUDGE
CLEAN
H_2O
TO SEWER
L.A. SANITATION
MONITORING
REPORT
M
DOHS
BI ANNUAL
REPORT
TRANSPORTER TREATMENT DISPOSAL
RECYCLE
TO SUPPLIER OR MANUFACTURER
INCINERATION
LAND FILL UNTIL 1990
TREATMENT FACILITY
TREATED WASTE WASTE RESIDUAL REPOSITORY

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FIGURE 2

NORTHROP CORPORATION-ADVANCED SYSTEMS DIVISION-1984

SOLVENT WASTE

Waste		Quantity (Gallons)	
Isopropanol and Waste		1,400	
Paint Thinner		1,000	
Acetone		20	
Kerosene		20	
	Total	2,440	
		-1,420	Landfill
		1,020	Recycle/Incineration (Approx. 3.5 tons)

FIGURE 3

NORTHROP CORPORATION-ADVANCED SYSTEMS DIVISION-1985

SOLVENT WASTE

Waste	Quantity (Gallons)	
Isopropanol and Water	14,370	
Mixed Solvents N.O.S.	450	
Paint Thinner	55	
Toluene	32	
Total	14,907	
	- 2,287	Landfill
	12,620	Recycled/Incinerated (Approx. 44 tons)

FIGURE 4

NORTHROP CORPORATION-ADVANCED SYSTEMS DIVISION-1986 (THROUGH 8/1/86)

SOLVENT WASTE

Waste		Quantity (Gallons)	
Isopropanol and Water		28,685	
Mixed Solvents, N.O.S.		1,008	
Paint Thinner		408	
Methyl Ethyl Ketone (MEK)		216	
111, Trichloroethane		165	
Naptha		50	
	Total	30,532	
		- 10	To Class I Landfill
		30,532	Recycled/Incinerated (Approx. 106 tons)

STATE REGULATORY OVERVIEW

by
Jan Radimsky
Department of Health Services
Toxic Substances Control Division
Alternative Technology and Policy Development Section
Sacramento, California

The presentation will highlight present and upcoming state statutory and regulatory requirements specifically related to the management of hazardous wastes containing solvents. The following topics will be covered:

- Reporting on waste reduction activities;
- Transportation;
- Permitting for treatment and recycling;
- New fees; and
- An update on recently enacted legislation which will affect solvent waste management in California.

RECYCLING AND INCINERATION OF HAZARDOUS WASTE SOLVENTS: ECONOMIC AND POLICY ASPECTS

Seymour I. Schwartz
University of California, Davis

PROBLEM DEFINITION

Many private sector firms face the decision of whether to change their methods of hazardous waste management. For some firms, the contemplated change is from disposal off-site to on-site recycling or process change (source reduction). For other firms, the decision is whether to go from illegal disposal to legal methods (or vice versa). In making these decisions, firms will generally want to know which technologies are available, how much they cost, and what are the uncertainties (potential penalties for using illegal methods or liability for damages, if legal methods cause health damages or require cleanup in the future).

Public sector decisionmakers face the question of how to design programs that promote waste management methods that reduce the threat from hazardous wastes. This usually means methods -- regulations and incentives -- that encourage source reduction, recycling, and treatment rather than land disposal. They also need information about the technological options, and the economics of those options.

Other participants in this conference will be describing the technological options available for better management of solvent wastes. I will concentrate on the economics of small-scale recycling and incineration, policy implications of these calculations, and approaches for improving waste management by small-quantity generators (SQGs).

The technology (including collection services) is available, although smaller firms may not know about it. Not only is the technology for solvent recovery available, it is widely used. My study of the electronics industry's hazardous waste management (Schwartz et al., 1985) found that most of the solvent wastes generated by the electronics industry were being recycled by commercial recyclers. Waste solvents produced by paint and ink manufacturers are also largely recycled; furthermore, these firms buy large amounts of recovered solvents as inputs to their production processes. Recycling capacity in Northern California in late 1984 was 8.5 million gallons per year (approximately 34,000 tons per year) — a very considerable amount. Thus, the problem is not a lack of recycling capacity; to some firms, the problem may be whether to install recycling equipment on-site (and obtain economic benefits) rather than paying to ship waste solvents for off-site recovery; for other firms, often small-quantity generators, the decision problem may be whether to pay a waste management firm to pick up its wastes rather than dump it in drains or sewers.

RECYCLING

I conducted an analysis of the costs and benefits to a private firm of small-scale solvent recycling (recovery) using commercially available distillation equipment. The distillation systems vary in size from 1.25 gallons per hour (the smallest available) to 25 gallons per hour. I obtained information about operating characteristics, and the costs of the equipment, installation, labor, materials, and utilities from one manufacturer and from several users of the system. These systems do not require a RCRA permit, which would be expensive, and so I assume that there are no permit costs.

To estimate benefits, I obtained information about the market prices of virgin and recycled solvents from three of the largest commercial recyclers in Northern California (for six solvents). The benefits are the dollar value of the savings to the firm from using recovered solvents; if the firm would normally have used recycled solvents, the value is calculated using the price of recycled solvents (normally about 20% less than the price of virgin solvent). Taxes are calculated using the new federal tax rates and depreciation guidelines. I assume that the equipment will be depreciated using the 200% declining balance method for a seven-year life (Wall Street Journal, August 18, 1986, p. 1).

The economic desirability of the investment is measured by calculating the net present value,[1] and the after-tax rate-of-return. To determine the sensitivity of the investment's desirability to the price of the solvent, which could change substantially due to market conditions, I performed a sensitivity analysis for different values of solvent price.

Assumptions: Small System[2]

a. Capital cost = \$5,000
b. Installation cost = \$2,000 (40% of capital cost)
c. Useful life = 10 years
d. Operating time: 1 shift = 2,080 hours per year
 3 shifts = 7,200 hours per year (83% of maximum time)
e. Yield (output rate) = 1.25 gallons per hour.
f. Operating cost = \$.30 per gallon (remains constant in 1985 dollars)
g. Income tax rate: Federal: 34% (new rate); State: 9.6%.
h. Depreciation: Federal: 200% declining balance; 7 year property.
 State: 200% declining balance; 15 year property.
i. Discount rate = 10 percent (real rate, not including inflation).
j. Market price of reclaimed solvent[3] = \$3.80 per gallon
l. Sensitivity analysis conducted for value of TCA at 50% of the current market price.

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[1] The net present value is the discounted present value of the net annual benefits minus the initial capital and installation cost.

[2] Assumptions for operating characteristics and cost based on data from (Church, 1985).

[3] Average price for 1-1-1 trichloroethane (TCA) in 1985.

Medium-size System[4]

a. Capital cost = $15,000
b. Installation cost = $5,000
c. Useful life = 10 years
d. Operating time: 1 shift = 2,080 hours per year
3 shifts = 6,240 hours per year (5 day week)
e. Yield (output rate) = 4.375 gallons per hour for 1 shift operation
6.875 gallons per hour for 3 shift operation
f. Other assumptions are the same as for the small scale system

Large System

a. Capital cost = $25,000
b. Installation cost = $5,000
c. Useful life = 10 years
d. Operating time: 1 shift = 2,080 hours per year
3 shifts = 7,200 hours per year
e. Yield (output rate) = 15 gallons per hour[5]
f. Other assumptions are the same as for the small scale system.

Results

Capital cost per gallon. The capital cost per gallon depends on the annual output (yield) of the recycling system. The after-tax capital costs for one-shift operation are $0.30 per gallon for the small system and $0.10 per gallon for the large system. For three-shift operation the respective costs are $0.09 and $0.03 per gallon.

Total cost per gallon. The total after-tax cost per gallon (the sum of the after-tax capital cost and operating cost) varies from a high of $0.47 per gallon (small system; one shift) to a low of $0.20 per gallon (large system; three shifts).

Net present value and internal-rate of return of the investment. The net present value (NPV) of the investment, based on after-tax cash flow, is calculated at a 10 percent discount rate (Table 1). At a solvent price of $3.80, the NPVs vary from a low of $27,429 (small system; one shift) to a high of $1.351 million (large system; three shifts). The corresponding internal-rates-of-return for these low and high conditions are 81.0% and 723.9%.

---

[4] These assumptions reflect the actual and potential operating conditions of a particular installed system at Varian Corporation; the higher output rate for three shift operation is based on an estimate by a company manager. We use a slightly higher operating cost than was estimated by Varian to allow for uniform comparison with the other systems we examine.

[5] Even though the system's manufacturer rates their large system at 25 gallons per hour, we use a more conservative estimate. Our assumption in no way reflects on the performance of the system.

Table 1. Net Present Value and Internal Rate-of-Return (After-taxes), of Investment in Solvent Recycling Equipment.[a]

Size of unit/ Price of solvent	One-shift Operation Net Present Value ($)	One-shift Operation Rate-of-return (%)	Three-shift Operation Net Present Value ($)	Three-shift Operation Rate-of-return (%)
SMALL UNIT:				
Price = $3.80	$ 27,429	81.0 %	$ 108,885	264.5 %
Price = 1.90	9,464	37.7	46,702	125.0
MEDIUM UNIT:				
Price = 3.80	166,016	150.9	530,022	435.3
Price = 1.90	67,214	80.0	233,617	204.1
LARGE UNIT:				
Price = 3.80	373,785	216.7	1,351,000	723.9
Price = 1.90	158,218	103.2	605,062	337.1

[a] Principal Assumptions (see text for greater detail):

- Operating and maintenance costs = $0.30 per gallon.
- After-Tax cash flow calculated using new tax law.
- Net present value calculated at 10% discount rate (note that net present value has initial capital cost subtracted from discounted benefits).

At a solvent price of $1.90, which is 50% below the baseline price and lower than any of the prices we obtained, the NPV varies from $9,465 (small system; one shift) to $605,062 (large system, 3 shifts); the corresponding internal rates-of-return vary from a low of 37.7% to a high 337%. These are extraordinarily high rates of return, even at a solvent price that is 50% below the baseline price. Thus, even under the most conservative assumptions, an investment in small-scale recycling should pay itself back in less than two years, and under many conditions, in less than one year. If Freon-113, which has a market price nearly three times that of TCA ($9.73 per gallon versus $3.80), these investments should pay themselves back in a few months, at most.

SMALL SCALE INCINERATION

The cost analysis of incineration was performed with the electronics industry in mind (Schwartz, 1985), but it should be applicable to other industries. Electronics firms typically generate halogenated as well as nonhalogenated organic solvents, both of which can be destroyed by incineration. The incinerator analyzed below is assumed to be capable of handling 3,000 tons per year, which, if all were solvent waste, would require about 3,000 gallons per day (based on a 250 day work year). It would take a large electronics firm or a consortium of nearby firms to support such an incinerator.

Description of the System and Assumptions

Heating value of the waste. Electronics firms often generate highly chlorinated waste compounds such as perchlorethylene, trichloroethylene, trichloroethane, methyl chloride and various freons. These halogenated compounds have a low heating value, so they are usually blended with other wastes or with auxiliary fuel until the chlorine content is reduced to about 30% (Dillon, 1981). Even after blending, the wastestream is still highly halogenated and has a fairly low average heating value (about 5000 BTU/lb.) To increase the hydrogen-to-chlorine ratio for better pollution control and to bring the heating value of the wastes up to 8000 BTU/lb, which is considered standard operating practice in the hazardous waste industry (Dillon, 1981), we assume that natural gas is used as a supplemental fuel.

Type of incinerator. There are three candidate incinerators for onsite use. The rotary kiln is the most versatile for destroying different types of wastes, but is also considerably more expensive than the hearth or liquid injection types. For destroying solvents, the liquid injection incinerator, which can burn halogenated organic liquids and slurries, is an appropriate choice. Therefore, our cost estimates are for a liquid injection incinerator.

Incinerator size. We assume that a consortium of electronics manufacturing firms can suppport, at most, a 3000 ton/year incinerator. Assuming the facility operates 7,200 hrs/yr (about 83% of capacity) and burns a waste-fuel mixture with a heating value of 8000 BTU/lb, the system should be sized to produce about 6.7 million BTU/hr (Vogel and Martin, 1983a). This value is representative of current onsite liquid injection incinerators, which typically operate at between 5 and 10 million BTU/hr (Vogel and Martin, 1983a).

Air pollution control. An important part of the capital investment is for air pollution control equipment. We assume that the incineration facility is required to install "best available control technology" in conformity with requirements of the federal Clean Air Act and state implementation plans. Following Vogel and Martin, we assume that the air pollution equipment consists of a quench chamber, venturi scrubber, and packed-tower absorber. Large volumes of water are needed for the scrubber (approximately 35 million gallons/year). The scrubber liquid is presently not classified as a hazardous waste and can therefore be disposed in a sewer (Ericksson, 1985). If the scrubber liquid has to be treated as a hazardous waste, the cost of incineration would become prohibitive.

Calculation of Capital Cost

The calculation of capital costs is based on Vogel and Martin's generalized curves, which are derived from their detailed model, and are accurate to within 30%. These curves provide uninstalled equipment costs in 1981 dollars, which we converted to 1984 dollars using the Chemical Engineering Plant Cost Index. Installation, engineering, instrumentation and spare parts, startup, and permitting costs are added to arrive at total installed capital cost.

We estimate that a 6.7 million BTU/hr liquid injection incinerator, including air pollution control equipment, will cost approximately $267,000 in 1984 dollars. Additional capital costs are figured as percentages of equipment costs: installation (50%), startup (10%), instrumentation (20%), spare parts (8%), and engineering (7%). Thus, equipment costs are increased by 95% to arrive at total installed cost.

Permit costs. The costs for obtaining a permit, including a trial burn, are considerable. One source estimates that the permitting procedure, including test burns, can cost $200,000 for a medium-sized incinerator (Chemical Week, 5 October 1983). The California Air Resources Board estimates the costs of a RCRA trial burn at between $100,000 and $300,000 due to the complex sampling and analytical procedures required (ARB, 1983, p. A-38). Based on these sources, we estimate that a small onsite facility of the type we analyze would cost approximately $100,000 for test burns and other activities mandated by RCRA.

The total capital investment, including installation and permitting costs, is estimated at $620,000. Of this amount, $320,000 is assumed to be depreciable for tax calculations.

Operating Costs

Labor. Vogel and Martin give typical salaries and personnel requirements for operating a larger rotary kiln incinerator (18,000 tons per year), and indicate that the labor requirements for an onsite liquid injection facility are considerably lower than this. Based on their data, we estimate that the labor needed for a liquid injection facility is one operator (one person for one-third of each shift), two yard-crew workers, and one-half person-year of supervisor. The estimated labor cost based on these assumptions is $104,200 per year. However, other studies show higher labor costs, so we also perform the analysis for a high labor cost of $171,500 (based on Dillon, 1981).

Utility costs. Utility requirements include water for the air pollution control equipment, electricity to run pumps and blowers, and auxiliary fuel needed to sustain combustion. In addition, caustic soda or hydrated lime is necessary to operate the gas absorbers in the air pollution control system. All of these cost items were estimated based on Vogel and Martin's models and some of their data (see Table 2 for details).

Disposal costs. Disposal costs are related to the ash content of the waste and the volume of scrubber effluent. Ash content is assumed to be

Table 2. Details of Calculation of Capital Costs, Operation and Maintenance Costs, and Energy Recovery Benefits.

CAPITAL COSTS:

Incinerator and air pollution control equipment	$ 267,000
Installation, startup, instrumentation, spare parts, and engineering	253,000
Trial burns and permits	100,000
TOTAL CAPITAL COSTS....................................	$ 620,000

ANNUAL OPERATING COSTS:

LABOR	
Low labor cost assumption	104,200
High labor cost assumption	171,500
UTILITIES	
• Water need = 35.28 x 10^6 gal/yr	
With 50% recycling of water:	
Water cost = 0.5 (35.28 x 10^6 gal/yr) ($0.80/1000 gal)	14,100
• Chemicals = (2.5 x 10^6 lb lime/yr) ($0.0155/lb)	38,100
• Electricity (for blower and pump, total 54 hp) = 290,000 kwh/yr	
Electricity cost = (290,000 khw/yr) ($0.08/kwh)	23,200
• Supplementary fuel (natural gas; 34.0 x 10^9 BTU/yr. needed)	
Fuel cost = (34.0 x 10^9 BTU/yr) ($5.20/$10^6$ BTU)	176,900
DISPOSAL	
Scrubber liquid = (35.28 x 10^6 gal/year) ($1.20/1000 gal)	42,300
Ash residual = negligible cost	
MAINTENANCE (5% of capital cost[a] = .05(520,000))	26,000
INSURANCE AND TAXES (5% of capital cost)	26,000
TOTAL OPERATING AND MAINTENANCE COSTS (LOW LABOR COST)......	$ 450,800
TOTAL OPERATING AND MAINTENANCE COSTS (HIGH LABOR COST).....	$ 518,100

RECOVERED ENERGY:

- Steam recovered (at 60% recovery) = 4.02 x 10^6 BTU/hr
- Energy needed from natural gas to operate boiler (@ 80% boiler efficiency) = 5.03 x 10^6 BTU
- Value of steam = (5.03 x 10^6) (7200 hr/yr) ($5.20/$10^6$ BTU) .....$ 188,300

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[a] Cost of trial burn and permit not included for calculation of maintenance cost.

quite low, and ash disposal costs are negligible. Costs for the disposal of scrubber liquid were based on the treatment assumptions used by Vogel and Martin. As we note above, the cost of disposing of scrubber liquid is based on the assumption that the scrubber liquid does not require treatment as a hazardous waste, which is presently a valid assumption (see Table 2).

Maintenance, insurance and taxes. Remaining annual costs are for maintenance, property taxes and insurance. Maintenance is figured at 5% of installed costs (Vogel and Martin, 1983) and insurance and taxes together at 5% of capital costs. The estimate for insurance may be low, because of recent large increase in insurance rates for environmental impairment liability insurance (such insurance is difficult to obtain, regardless of rates). This recent development could have a major impact on the cost of small-scale incineration or other waste treatment activities which require liability insurance (or self-insurance) in order to obtain a permit to operate the waste treatment process.

Benefits

Energy Recovery. If an energy recovery system is used, the overall investment becomes more desirable because much of the waste heat generated by the high combustion temperatures can be recovered as valuable steam. Since as many as 90% of incinerators have energy recovery systems (California DOHS, 1984) we assume that energy recovery will be used. The benefit is the cost savings from not buying natural gas to to produce the same amount of energy. We assume, conservatively, that 60% of the thermal energy is recovered from the incinerator, and that the boiler is 80% efficient. Natural gas price is assumed to be $5.20 per million BTU.

Tax Effects

Since the incinerator does not produce energy benefits that exceed costs, the calculation of tax effects is somewhat different than for recycling. Depreciation charges and operating costs are simply deducted from other income that the firm earns, so there is a tax benefit. As the tabulated numbers show, the after-tax cost is about one-third less than the pre-tax cost.

Results

Since incinerators result in a cost to the firm (which might be lower than the cost of existing waste management methods), the cost per ton of waste destroyed by the incinerator is the measure used to judge the investment. First, the discounted present value of the cost, over the assumed 15 year life of the incinerator, is calculated at a discount rate of 10%. This present value is then converted to an annualized cost, which is divided by the number of tons per year incinerated to give the cost per ton.

For the baseline conditions described above, and the low labor cost assumption ($104,200 per year), the total cost per ton of incineration is $41.33 (Table 3). By comparison, the pretax cost is $57.68 per ton. At the high labor cost, the cost per ton is $54.38 whereas the pretax cost is $79.49.

Table 3. Cost per ton of Hazardous Waste Solvent Treated by Incineration.

	Cost per Ton ($)[a]	
	High Labor Cost	Low Labor Cost
Baseline — Pre-tax	$79.49	57.68
Baseline — After-tax	54.38	41.33
With ITC = 25%	50.38	37.36
ITC = 30%	49.58	36.57
ITC = 35%	48.79	35.78

[a] Conditions and assumptions:

- Capital cost = $620,000 ($320,000 is depreciable)
- Annual operating & maintenance cost (low labor cost) = $450,800
- Annual operating & maintenance cost (high labor cost) = $518,100
- Energy recovery benefit = $188,300 per year
- Depreciation: Federal: 200% DB, 7 year life
  California: 200% DB, 15 year life

These are lower cost estimates than are typically reported in the literature, where estimates in the $200 and higher range are common (see Schwartz et al. 1985 for a review of these studies). However, the California Air Resources Board (ARB, 1983) estimated the cost for liquid injection incinerators in the range of $30 to $95 per ton, which is consistent with my estimates. Very high estimates are likely to be for more expensive types of incinerators and for very toxic wastes (e.g., PCBs).

The Effect of Tax Incentives on Incineration Costs

A standard policy approach to encourage the use of certain technologies is to offer tax credits or other tax incentives. A bill to provide a state investment tax credit (ITC) was introduced in 1985 by Senator David Roberti (S.B. 471) but was not enacted into law. The bill would have given an ITC of 25% for treatment equipment, 30% for recycling, and 35% for source reduction investments. The effect of such an incentive would be to reduce the state tax of a firm by the amount of the tax credit, but it would also increase the federal tax, as the deduction on the federal tax return for state taxes would be reduced.

The results for the three levels of a state investment tax credit are tabulated in Table 3 for high and low labor cost. It is clear that an investment tax credit offered by the state does not reduce the cost of incineration by much — the 25% credit which would have been available had the Roberti bill become law reduces the cost by only 8% to 10%.

SMALL QUANTITY GENERATORS

It seems appropriate to comment on the special problems of managing hazardous waste management produced by small quantity generators (SQGs). This is a subject I have been doing research on, and I think it is important. My research assistants have interviewed managers of public programs and private waste management firms throughout the U.S. and Canada. They asked about their programs and also about their perceptions of the behavior of SQGs. The dominant finding that emerges from our study, and is supported by other studies of SQGs, is that illegal disposal is very widespread among SQGs. Lack of knowledge of regulations and alternatives is an important reason for illegal disposal, but an equally important reason is the unwillingness of SQGs to pay the extra cost of legal disposal. Many SQGs do not perceive a serious threat of penalties for disposing illegally, and hence they see little incentive for changing to legal methods, which are more expensive.

I think it is instructive to to look at the most successful example of waste management in the SQG field. I cannot avoid using a company name here. Safety Kleen provides a device for cleaning auto parts to more than 250,000 auto service and repair shops throughout the nation. Safety Kleen delivers clean solvent for use in a patented parts cleaner, which they supply, and picks up the dirty solvent on a regular basis. Safety Kleen collects the used solvent, recycles it in large regional distillation facilities, and reuses the recovered solvent. Safety Kleen clearly provides a valuable waste management service to its clients and it essentially relieves them of liability if the auto repair shops use the equipment properly. What is notable is that this service was started long before there were hazardous waste regulations — Safety Kleen was providing a service (parts cleaning) to auto repair shops which enabled the repair shops to operate more cheaply and efficiently. The auto repair shop cannot match the cost of Safety Kleen's service even if it disposed of its spent solvent illegally at zero cost. Thus, the waste management portion of the service Safety Kleen provides is essentially free.

Safety Kleen and Roehl Disposal are providing similar services to dry cleaning firms, which use larger amounts of solvents than auto repair shops. There are differences in the structure of the two industries, which probably makes it harder to sign up clients in dry cleaning industry, but these firms seem to be doing well at enrolling dry cleaners. In other industries with large numbers of SQGs, it may be more difficult to enroll clients because of the way in which solvents and other hazardous materials are used. It should also be kept in mind that Safety Kleen only solves the hazardous waste disposal problem for one type of hazardous waste in the auto repair industry — illegal disposal is still a problem for other types of wastes (oils, batteries, acids and caustics).

I think there are a few implications for policymakers. For SQGs the primary alternative for legal disposal will be pickup of wastes by licensed waste disposal firms; most SQGs will not find onsite recovery or treatment feasible, although some, such as dry cleaners, may generate enough solvent waste to recycle onsite. When the extra cost paid for waste management is low, as in the auto repair industry, it is possible to enroll most firms (Safety Kleen typically enrolls more than 90% of the auto service and repair shops in the areas it chooses to enter). If an important service, needed by the SQG to operate effectively, is provided along with the waste pickup service, participation is likely to be high. However, small firms are very sensitive to cost and many are unwilling to spend as little as $50 per month for managing their hazardous wastes legally (ABAG, 1985). Several of the waste management firms we interviewed told us about loss of customers when costs increased or when an EPA identification number was required (at a charge to the SQG). In most cases, when a SQG discontinued service from a waste management firm, its only alternative was illegal disposal.

Clearly, increasing the perceived cost of illegal disposal is one way to gain increased compliance. This means more effective enforcement and more stringent penalties for illegal behavior. I think this approach is essential, but it is not easy and it is not enough. First, the cost of enforcement directed at SQGs is beyond the resources of the Department of Health Services; it is difficult to envision a state-run enforcement program that would inspect more than a small fraction of SQGs. (Local governments can help greatly by developing their own inspection and enforcement programs; Ventura County's program looks especially promising.) However, random audits (inspections) could be effective if the penalties for illegal behavior are severe.

The other part of a more effective waste management strategy should be the availability, at least to SQGs, of low cost legal alternatives for waste disposal. It seems to me that subsidizing waste management firms to provide low cost pickup and disposal services is potentially more effective than subsidizing the SQGs. If waste management firms could provide a monthly pickup for say $20 per month, with the balance of the true cost of the service provided by grants from the state, I would expect noncompliance to decline sharply. The state would be providing grants to a handful of waste management firms rather than to tens of thousands of SQGs, and relying on the ability of the waste management firms to sell their service to SQGs. I am impressed by the potential of waste management firms to market their services; in the process of marketing their services they will be educating small generators about legal requirements. My guess is that this type of direct persuasion will be more effective in getting SQGs to comply than informational programs run by state agencies. Why not pay waste management firms a bonus for signing up new customers (conditional on the length of time the customer stays)?

CONCLUDING COMMENTS

For managing hazardous waste solvents, recycling (recovery) by commercially available distillation systems is the clear choice for all firms that produce more than eight gallons per day of solvent (about 580 kg/month). In fact, my calculations show that solvent recycling is so economically profitable that any firm that generates more than this minimum amount of solvent should install a recycling system onsite immediately. In addition to the economic benefit, there is a slight reduction in liability from the shipping of wastes to a commercial recycler.

Incineration, while much less economically attractive for solvents than recycling, is an economically viable option when compared to land disposal. However, ownership of an incinerator by a firm or a consortium of firms would be feasible only for quite large generators or for waste management firms. Incineration is also certain to face problems in the permit and approval process at the local level. For any solvent that can be recovered by distillation, there is no advantage to incineration.

As a policy incentive for promoting investments in technology to reduce hazardous wastes, a state investment tax credit is not appealing for several reasons: it does not provide much of an incentive, only reducing the cost per ton by 8% to 10%; it is not needed for recycling equipment, since that option is already economically desirable; and, it is available to firms that would have invested in new equipment for production reasons rather than for waste reduction.

The strategy for economic incentives proposed by ICF Consultants (1985) is much better, as it addresses the barriers to adoption of desirable waste management technology and practices. ICF identifies two categories of barriers: technical and financial. Technical barriers include: lack of information, lack of expertise to evaluate and implement waste reduction methods, absence of waste reduction technology, and lack of awareness of waste management issues by decisionmakers (ICF, 1985; S-2). Financial barriers make the firm unable to raise funds for the project. I would add a third category, "lack of willingness or lack of incentive to comply," because the cost of complying is higher than the perceived cost of penalties for not complying. ICF recommends a program of grants, loan guarantees, and state-issued loans to overcome the identified barriers, with grants for information dissemination, waste audits, implementation, and research and development accounting for between 70% and 100% of the budget (depending on budget size). Waste audits would provide essential technical information that a firm needs in order to improve its waste management methods; implementation grants would reduce the financial barrier of inadequate access to capital (these are recommended only as a complement to loan guarantees); RD&D grants would encourage research, development, and demonstration of new waste reduction methods, thus removing the technical barrier of an absence of available technology (ICF, R-2).

I think the ICF recommendations are sound and I support them, but they do not fully address what I have identified as the third barrier, which can be viewed as an economic barrier — the lack of an incentive to invest in better methods (or legal methods) of waste management. As I discussed before, among SQGs this barrier is very important -- many SQGs are unwilling to pay quite small amounts to dispose legally. Larger generators currently using legal methods may not be willing to invest in better methods that reduce their profits. Only implementation grants, among ICF's proposed incentives, would reduce the cost to the waste generator; ICF does not discuss the need for increasing the cost of illegal disposal, a topic which was presumably outside the scope of their study. I believe that a broader array of subsidies (mainly through grants) should be considered — especially grants to waste management firms to provide low-cost services to small generators, and to operate transfer stations, which can lower costs. Changes in regulations for storage and handling of wastes in permitted transfer stations should be considered, as well as other regulations that can be relaxed without increasing the threat to human health. Finally, the perceived costs of illegal disposal must be increased by more stringent enforcement — more frequrent inspection and greater penalties for illegal disposal. Economic incentives alone are not likely to be enough.

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USE OF RECYCLENE MACHINES FOR SOLVENT RECOVERY IN INDUSTRIAL OR MILITARY APPLICATIONS

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INTRODUCTION

"There are four reasons why it makes sense to recycle your waste solvents with a machine in your facility. One - it will save you money. Two - it will save you money. Three - it will save you money and four you will be able to comply with EPA and State rules and regulations with less of the onerous paperwork requirements that exist if you ship your waste material outside your plant.

If you could stop using solvents in your plant and use water to degrease your parts or clean your painting equipment you would do so. Obviously, you can't and that's why you're continuing to use solvents. The solvents that you use are to wash something so you can assemble it, reuse a tool, or in some way clean the piece of equipment or material to go into process or product. Because most of the solvents are being used for this purpose, you are not buying laboratory quality solvents. You're not buying laboratory quality solvents from your supplier, nor from your reclaimer, nor when you are producing them yourself. I say this not to in any way, downgrade the quality of the product you will get out from an onsite recycling operation, but to point out that one must pay attention to why one is using the solvent when determining what you should be spending money for. The material coming out of a solvent recycling machine such as ours, is as pure as the material that you are buying from Dow, Exxon, Union Carbide or any of your local suppliers under various brand names. Since you're getting material out of your own in-plant solvent recycling machine of the same quality as you would buy commercially, the question is, which of these materials will cost you less. You have a classic "make-buy" decision with all the numbers coming out on the side of "make" or in this case reclamation of your own solvent.

The cost comparisons are dramatic. Solvent recovered from our onsite recycling machine will generally cost you about $.35 - $.50 per gallon. This includes labor (which is minimal), electricity to run the machine, water to condense the solvent, and our drum liners.

If you go purchase new and dispose of waste solvents, what we would call "buy and burn", i.e., incinerate or "buy and bury" i.e. landfill (soon to be illegal) your comparable costs for most solvents including purchase and disposal exceed $5 per gallon. For solvents like Trichlorethylene and 1.1.1. Trichlorethane a $6 to $7 total is usual for purchase and disposal. For some of the lower cost paint solvents and mineral spirits you might be in a $4 to $5 range. If you are dealing with exotic solvents, such as Freon, comparable figures are at the $15 and $16 per gallon level. Thus, the cost ratio of a solvent that you produce in your own machine vs new solvent ranges from 1:10 to 1:20. In the event that you elect to buy reclaimed solvents from the local offsite recycler, the comparable ratio is 1:6 to 1:10.

For the economic advantages alone, it is obvious that one ought to recycle on-site. Time after time, we make machine proposals and do an economic justification (on the forms such as these) that shows that machines can be purchased and fully paid for in three months to one year. This means a return on investment of 100% to 400%. These payback periods and return on capital investment are almost unheard of, and ought to be very attractive to your financial people.

In any make-buy comparison where you find a payback of 3-9 months and a return on investment of 125% - 400%, you should as quickly as possible move into a "make" mode.

There are a number of other advantages in producing your own solvent onsite. From a quality standpoint, our recycling machines return to you what you originally bought, with the contaminant that was picked up by the solvent in your wash or use process removed. When you send the material to an outside reclaimer, he doesn't take your discreet Xylene loaded with paint, and run it through his machine and return the same Xylene to you. It gets comingled with a whole series of other customer's paint and lacquer thinners and is run in a large factional distillation unit. You may get back Xylene, you may get back Xylene mixed with Toluene, M.E.K. Perhaps, it doesn't matter to you, but the quality control will never be as good as when you run the material through your own distillation process in-house. What you put in, is what you get out.

There are important environmental and environmental-legal advantages in recycling onsite. If you recycle in your own machine onsite for your own use, you are not required to get a permit of any sort. Onsite recycling does not trigger any permitting requirement; neither at the Federal or State level. On the contrary, when you send used solvent outside your plant gate for disposal or recycling, you enter the whole world of EPA regulations and paperwork. You must, at a very minimum, fill out a manifest describing what you're sending, to whom you're sending it and make a number of binding declarations.

The reason this manifest is required by EPA is because of their experience when material has been sent or turned over to third parties and then inproperly disposed of or handled and the third party, i.e., the disposer, transporter, incinerator operator, land fill operator or whomever, disappears into bankruptcy or from the physical reaches of enforcement authorities. The material ends up in ground water or poisoning the land. There is a provision in all of the recent hazardous waste laws that establishes a "cradle to grave" responsibility. It says that you may give it or sell it to someone else but your responsibility goes right with that material, FOREVER.

You never lose touch with hazardous waste nor responsibility for it. If its mishandled, or misapplied to the ground, misincinerated and even if there is an accident along the road for which the transporter cannot be found or cannot pay appropriate damages, it comes back to haunt you. That haunting can consist of fines and it can consist of jail terms. We have an ad from the February 12, Los Angeles Times written by the President and Vice President of American Caster Company announcing that illegal handling of hazardous waste can put you in jail and that's where the ad was written from. A judge in Los Angeles said that not only will there be a fine, not only will there be a jail term for the executives involved, but they will also write and pay for an ad in the city's biggest newspaper describing their mishandling of hazardous waste. More and more of the local prosecutors are coming back to the source of waste rather than just simply the landfill operator or transporter and saying that "cradle to grave" tag that EPA put on this material is not just a catchy phrase. This responsibility exists whether you give material to someone to dispose or whether to give the material to someone to recycle. You better make sure that if hazardous waste leaves your facility that it is going to someone who has financial responsibility, has the ability to remain in business and handles the material properly so that it will not come back to haunt you "from the grave".

In addition to the "cradle to grave" responsibility there is a phrase on this hazardous waste manifest in which you state that "I also certify that I have a program in place to reduce the volume and toxicity of waste generated to the degree I have determined to be economically practicable and I have selected the method of treatment, storage, or disposal currently available to me which minimizes the present and future threat to human health and the environment." If you recycle onsite EPA accepts that process as fulfilling this minimization declaration.

If you decide that the economic and environmental considerations make inhouse recycling sensible, what should you look for in a machine? The distillation process is rather simple. One boils the material and condenses the vapor. Distillation has gone on for hundreds of years. In its simplest form you can simulate it by running a tea kettle on your stove and putting a mirror above the tea kettle. You will be distilling and condensing the water in the kettle. However, in this case we are dealing with toxic, flammable and sometimes explosive solvents and contaminants. Therefore the considerations that we believe are most important, are safety and simplicity. Safety of operation, safety for your personnel, safety for your facility, are paramount in the machines that we build and the type machines we think you ought to be using for in-plant solvent recovery. The Recyclene solvent recovery machines all are built with numerous duplicative and redundant failsafe mechanisms. We do not build a machine designed to operate as a boiler. We do not design a machine built to allow pressure buildup. We build a machine where the solvent will be boiled at atmosphere pressure and condensed with a conventional water flow through condenser. We control that machine so that if anything deviates from the normal, the machine will automatically shut down.

Amongst the safety controls on the machine is a factory set max temperature thermostat. This is backed up by a thermostat that you set based upon the solvent you are boiling to control heating oil temperature. The machine also has an automatic shutoff device that senses when all the solvent has been distilled and you are just cooking contaminant. It throws the machine automatically into the quench and cooldown mode. In addition to being a safety device, this also permits automated operation when no one is in the plant.

Another thermostat detects the water temperature at the exit of the condenser. If the water temperature rises more than the programmed amount, it says that solvent may be coming through the unit as vapor and not being fully condensed and again it will call for an automatic quench and cooldown. Lastly, a control that is truly unique and only available on this machine, measures the lid temperature and prohibits opening of the lid until the machine has cooled down to a preset temperature. No one can come along and attempt to look in the oven and see whether the cake is done. All these controls are made with Underwriter Lab approved components. All are enclosed in explosion-proof boxes within the machine itself. Explosion-proof controls are essential and explosion-proof controls should not be located distant from the machines or sold as an option.

They are as integrals to the machine as the boiler and as essential as the condenser.

In addition to the machines being safe, they should be simple to operate. You don't want a machine that requires an operating engineer. You want a machine that requires minimum labor and allows a laborer at the lowest skill level to operate it. We have built such a machine. Once the temperature settings for the solvent you intend to run have been adjusted on the thermostats inside the machine, all one needs to do to have this machine operate is to get the solvent inside it, close the lid, and push a green button. Everything else will happen automatically. Putting the solvent into the machine can be done in a low volume operation with our RS-20 or in our nonautofill RS and RX-35 by pouring or hand pumping the material in through the open lid. The lid is then locked down, the green button is pushed, and the unit goes. For larger volume users, people who are generating a half drum or more of solvent a day, our larger autofill units make sense. In this case one doesn't even have to open the lid or pour material in. One simply hooks the machine up to a dirty drum or tank of solvent on the left side as you face it and ties in a clean drum to receive the solvent on the right side, pushes the button and our float actuated air-driven stainless steel pump will feed dirty material into the machine on a continuous basis and the clean solvent will come out into the drum on the other side.

In either case, batch or autofill operation, when the machine cools down, you will take the liner bag of dirty contaminant out of the machine, wipe the machines gasket and start again. A word about this liner. We place either a nylon or at high temperatures, a teflon liner into the machine much like you do with your garbage can or trash compactor at home, and much for the same reason. Neither you nor any member of your family wants to scrub out a dirty garbage can repeatedly. The the use of this liner lets you dry the material out and not have to clean the stainless steel boiler each time you use the machine.

Sometimes you will get material behind the liner and compromise the cleanliness on the machine, which is really the key maintenance item. But the liner reduces 90% of your cleanout activities and also permits you to distill more of your solvent and turn contaminate into a much drier residue.

Simplicity. Load it up, push the button and the machine goes through its cycle automatically, shutting itself down when it knows its done, cooling itself when done, and telling you, "I'm done, come take the cake out of the oven."

I've mentioned stainless steel. We used to build machines out of stainless or carbon steel depending on the corrosive characteristics of the solvent. We used to use rubber gasketing or teflon depending upon the characteristics of the solvent. No more. Everything is stainless, everything is teflon because the owner or operator who said I'm going to use material that is compatible with rubber and compatible with carbon steel found himself on Friday night with someone else in the plant bringing over another material and running it, eating the gasket apart, corroding the steel, and causing a phone call to us on Monday asking why the material didn't hold up. We don't know what's going to go into your machines, you generally know. But in the plant you are going to find the Recyclene machine becomes a very popular device and since the same machine can run multiple solvents, we are building it with stainless steel metal parts with teflon gasketing, with teflon fittings so that you can run any of the solvents listed on this sheet, from Freon to the chlorinateds, to lacquer thinners and alcohols, all with no concern as to the corrosive or destructive effect on any components.

We have made another decision relative to the heating of the solvents in our unit. In order to get uniform heat and to have a long life heater, we heat a high conductivity silicon oil with a calrod unit between the outer and inner stainless steel boiler shells. This silicon oil bath expands by 120% during the heating cycle and slides up the sides of the inner boiler so we are getting heating all the way up and around the boiler, not just across the bottom. This is important because the insulation level of the contaminant builds up, and if we were simply heating at the bottom, we would have a far less efficient unit.

Is this magical, reliable, simple to maintain unit the answer to every question and are there no problems with it? Of course not! Are there things that you can't do? Of course! Let me caution you about a couple. If you have material with nitrocellulose in the paint or lacquer or ink, you have to take extra precautions involving the addition of an additive prior to recycling. Nitrocellulose when dry, is an explosive and so you can't dry it out and heat it and not expect something to happen. An extra chemical addition step will have to take place. If you are treating the chlorinated solvents, trichlor, trichlorethylane, perchlor and you've let your material become acidic in your degreasing application water get to it, that acidic material, which has been eating away at your degreaser and etching the parts you put in, will also do a job on our cupro-nickel condenser. Therefore, you must not run acidic chlorinated solvents through this machine. Your solvent supplier, Dow or Union Carbide, has a kit called an acidic acceptance test that they will give you to make sure you are not generating acidic trichlor. If you are, you had a problem before we ever came on the scene because you were doing in your degreaser and to your parts. The Recyclene unit will not turn chlorinated solvents acidic, but it won't take acidic chlorinated solvents and restore them to their neutral condition. You must make sure you don't have acidic chlorinated solvents.

Other than that, the only caveat I would suggest is to watch our limit of 30% solids in your waste material. If you have a 50% or 60% solid, you will not be able to move it through the autofill unit and you will build up such a level of contaminant insulation inside the boiler that the unit will not be highly productive. There are almost no cases we have run into (except in some automated paint operations, where the operator decides to waste paint and pump good paint into the solvent stream by using solvent instead of air as the prepurge) that we run into these high contaminant levels, but again, this unit is designed for 30%. Don't go for more than that.

There are several steps we take in our sales process before we will sell you or rent you a machine. One, we insist that our distributors run a sample of your material in a machine that is set up in their shop. They will run the sample of dirty solvent that you have given them. They will bring you back your clean solvent. They will bring you back sample jars showing dirty, clean and sludge and they will bring you back a plastic bag with your sludge in it. This is for our purposes as much as yours. We want to make sure that we are selling you a machine that we know will work on the solvents you gave us. It also enables you to show samples of what was run so your people will know what they are going to get out of this machine when it becomes part of their production process. Additionally, we will do an economic justification analysis so that you know and we know the payback on this machine, and how long it will take for the money you have given us to be recaptured by solvent production cost saving.

We think it is very important that you look at this machine as a solvent producing machine. You are now spending money, sending it out every month to Dow or to the ABC Disposal Company. For that you are getting solvent that you use in your process. You can spend far less money and produce solvent inhouse. The capital cost of the Recycleneis recaptured in months.

You are going to keep on using solvents because you need to use them. EPA regulations are going to get tougher and the demands on your companys for cost savings in the production area are going to continue. We think that happy marriage of need, law and money savings will make us part of your world. We want to be part of it, and we look forward to working with you. Thank you for having us here today.

EPA's LAND DISPOSAL RESTRICTIONS PROGRAMS

Stephen R. Weil
Environmental Protection Agency

I. STATUTORY REQUIREMENTS

- A. PROHIBITION ON LAND DISPOSAL AND "NO MIGRATION"
- B. TREATMENT STANDARDS
- C. EFFECTIVE DATES AND EXTENSIONS
    1. Solvents and Dioxins - November 8, 1986
    2. "California List" - July 8, 1987
    3. Schedule for Other Wastes - August 8, 1988 - May 8, 1990
    4. National Capacity Extensions
    5. Case-by-Case Extensions
    6. Disposal Requirements During Extension
- D. UNDERGROUND INJECTION
- E. STORAGE

II. SOLVENTS & DIOXINS - THE NOVEMBER 8th RULE

- A. THE JANUARY 14, 1986 PROPOSAL AND SCREENING LEVELS
- B. THE NOVEMBER 8th RULE
    1. Framework - How We Set Treatment Standards
    2. Other Aspects - How We Set Petitions, Variances, Effective Dates
    3. Treatment Standards
    4. Effective Dates

III. THE "CALIFORNIA LIST" PROPOSED RULE

- A. STATUTORY REQUIREMENTS
- B. EPA's PROPOSAL
    1. Concentration Levels
    2. Treatment Standards
    3. Effective Dates

V. OTHER ACTIVITIES

- A. SCHEDULE FOR OTHER WASTES
- B. RELISTING

CHLORINATED SOLVENTS: THE REGULATORY DILEMMA

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P-7257

The Rand Corporation

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I. INTRODUCTION

There are thousands of businesses in the U.S. today that use hazardous substances in the course of producing their product or providing their service. This paper focuses on alternatives to land disposal for one class of these substances--halogenated solvents. These solvents are interesting because they pose a variety of health and environmental problems, they are used widely in a variety of diverse industries, and they are among the first substances to be banned from land disposal in November, 1986 under the Hazardous and Solid Waste Amendments (HSWA) to the Resource Conservation and Recovery Act (RCRA).

There are five major halogenated solvents--1,1,2-trichloro-1,2,2-trifluoroethane (CFC-113), methylene chloride (METH), perchloroethylene (PERC), trichloroethylene (TCE) and 1,1,1-trichloroethane (TCA). Although these solvents are used for a number of different purposes, much of the waste is generated primarily in three industries--metal cleaning, electronics, and dry cleaning. It is these three sectors I concentrate on here.

All five chlorinated solvents are presently under regulatory scrutiny by the Environmental Protection Agency (EPA), sometimes for more than one reason. A significant problem that confounds the decision to regulate is that the chlorinated solvents are substitutes for one another in various end uses so that regulating one of them may increase use of another that is perhaps as dangerous but in a different way. Moreover, substitutes outside the chlorinated solvent class may also be dangerous and regulators must be aware of the tradeoffs. Thus, any regulation imposed on solvents must consider the class in concert and also must consider that users may move to substitutes outside the chemical class.

In this light then, this paper is a characterization of halogenated solvent use in three primary industries where solvents are used. It reports the results of research on solvent use and disposal practices in metal cleaning, electronics, and dry cleaning. It also emphasizes that the only effective way of identifying alternatives to land disposal is to understand the circumstances and life cycle of the solvents. In addition, it recognizes that the regulations on hazardous waste that affect these solvents must be considered in the context of other regulations.

There are three major aims of this work. The first is to develop a profile of the concerned industries. The second is to examine the regulatory history of the solvents and their interrelationships with one another to place in context the regulations on hazardous waste that now affect most users. The third is to suggest mechanisms of using alternatives to land disposal for managing solvent waste.

With these aims in mind, in Section II I describe the solvent life cycle in the three major industries. I track the halogenated solvents from production, through use, and finally through emissions and disposal.

In Section III, I describe the health and environmental effects of the solvents and discuss the regulations that affect the industries of focus. In this light, I present two historical case studies which illustrate the importance of considering the complete regulatory environment and the interactions among the chemicals. This prepares the way for examining the context in which regulations affecting hazardous waste can be evaluated.

In Section IV, I focus on the hazardous waste regulatory regime that is increasingly affecting solvent users. I discuss the potential for recovery and reuse of spent solvents and cite two detailed examples where reclamation has effectively reduced virgin solvent use and waste generation.

In Section V, I summarize the results and draw some conclusions from the analysis.

II. SOLVENT LIFE CYCLE

In this section, I present an overview of the five solvents with special emphasis on developing a profile for the industries of interest. In what follows, I track the solvents through their life cycle from production through emissions and disposal.

SOLVENT PRODUCTION AND VIRGIN DEMAND

Table II-1 shows production and demand levels for each solvent for a recent year--1984. The values for virgin demand were determined by subtracting exports and adding imports to the production figures.

The values of Table II-1 show that in general, demand exceeded production. This was the case in 1984 because the strong dollar caused increased imports and decreased exports.

Table II-1

HALOGENATED SOLVENTS PRODUCTION AND VIRGIN DEMAND - 1984

(thousand metric tons)

SOLVENT	PRODUCTION	VIRGIN DEMAND[a]
TCE	86	91
PERC	260	307
TCA	306	337
METH	275	279
CFC-113	68	68

[a] Demand is equal to production minus exports plus imports.

Source: ITC (1984); Bureau of Commerce (1984); Hammitt et al, (1986).

According to Table II-1, demand for PERC, TCA, and METH is high--around 300 thousand metric tons (mt) annually for each. Indeed, demand for the three solvents has remained approximately constant with some fluctuations for the most recent six years. Demand for TCE is about one-third that of the other three solvents. Although TCE was once the most widely used solvent, demand has declined significantly in the last 15 years. As we see later this is largely a consequence of regulations on emissions. CFC-113 demand is the lowest of the solvents but has grown substantially in the last five years--about 8 percent annually.

SOLVENT END USE

Solvents are used in a variety of diverse ways including as intermediates, in aerosol formulations, in paints and in paint remover. In this analysis, I focus on the major waste generating end uses.[1] These include: metal cleaning which is comprised of cold cleaning, where the solvent remains at room temperature and vapor degreasing, where the solvent is heated to its boiling point; electronics which involves cleaning of high technology equipment; and the dry cleaning of clothing.

Different sources have estimated the level of solvents devoted to various applications (CMR, 1983; CMR, 1986; EPA, 1981). Some of these data are incorrect or do not agree with one another. Using the data together with industry information and correcting for inconsistencies, I show estimates of virgin solvent use in three major applications in Table II-2.

The values of the table show that all five solvents are used in cold cleaning and vapor degreasing whereas only three-TCA, METH, and CFC-113--are used in electronics and two--PERC and CFC-113--are used in dry cleaning. Solvent use in vapor degreasing and cold cleaning is approximately equal and is larger than use in the other applications. Dry cleaning use, largely PERC, is the next largest end use followed by electronics.

SOLVENT EMISSIONS

One source estimates that atmospheric emissions from metal cleaning operations amount to 84 percent of virgin solvent use (EPA, 1981).[2]

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[1] Solvent use in applications like aerosols and paints rely on its ready vaporization. Thus, emissions rather than waste are the primary loss mechanism. The one application I exclude that does generate a substantial amount of waste is paint remover which accounts for about 60 thousand mt of METH's demand.

[2] In principle, one might expect emissions of TCE and PERC to be lower than those of the other solvents because they are more strictly controlled as smog contributors (see next section). However emission capture techniques, like carbon adsorption for instance, simply prevent emissions allowing the solvent to be recovered for reuse. Total solvent use includes both the contribution of the virgin material and the recovered material. The key point here is that emissions as a fraction of virgin solvent use are not altered in this process.

Table II-2

VIRGIN SOLVENT USE IN MAJOR APPLICATIONS - 1984

(thousand metric tons)

SOLVENT	COLD CLEANING	VAPOR DEGREASING	ELECTRONICS	DRY CLEANING
TCE	18	62	-	-
PERC	16	38	-	130
TCA	143	79	21	-
METH	12	6	21	-
CFC-113	16	5	34	2
TOTAL	205	190	76	132

Source: CMR (1983); CMR (1986); EPA (1981), Rand estimates.

There is no reason to expect a different value would apply to electronics where the operation is similar to metal cleaning. For dry cleaning, emissions are higher--perhaps 88 percent. Table II-3 presents emissions estimates based on these assumption.

SOLVENT WASTE

A small amount of each solvent ends up in water. EPA (1981) estimates this value at 2 percent of use. Because of more stringent regulations on water releases in more recent years, I assume water releases to be lower--1 percent for metal cleaning applications and electronics and negligible for dry cleaning.

Table II-4 presents estimates of the waste generated in the analyzed industries. In all cases, the waste level is equal to the difference between solvent use on the one hand and emissions plus water releases on the other hand.

FACTORS AFFECTING SOLVENT ESTIMATES

I note here that some of the solvent is used in combination with other components in metal cleaning and particularly in electronics. Specifically, a large amount of the CFC-113 is combined with various alcohols; there are combinations of some of the other solvents as well.

Table II-3

SOLVENT EMISSIONS IN MAJOR APPLICATIONS - 1984

(thousand metric tons)

			END USE	
SOLVENT	COLD CLEANING	VAPOR DEGREASING	ELECTRONICS	DRY CLEANING
TCE	15	52	-	-
PERC	13	32	-	114
TCA	120	66	18	-
METH	10	5	18	-
CFC-113	13	4	29	1.8
TOTAL	171	159	65	116

Source: For cold cleaning, vapor degreasing and electronics, values equal 84 percent of figures in Table II-2; for dry cleaning, values, equal 88 percent.

At most, the second component of these combinations increases the weight of solvent used by about 15 percent. The volume increase would be somewhat less because the density of the second component is commonly less than that of the solvents. Including these second components would increase use and correspondingly the amount of waste generated.

Another factor that acts to increase the waste is contamination. Solvents can no longer clean effectively when their contamination level amounts to between 10 and 20 percent. Thus, the weight of waste generated may be higher than the figures of Table II-4 by some 15 percent. Again, the volume increase would be smaller--in this case because the density of soils and other contaminants is less than that of the solvents.

Table II-4

SOLVENT WASTE GENERATION IN MAJOR APPLICATIONS - 1984

(thousand metric tons)

SOLVENT	COLD CLEANING	VAPOR DEGREASING	END USE ELECTRONICS	DRY CLEANING
TCE	3	9	-	-
PERC	3	6	-	16
TCA	22	12	3	-
METH	2	1	3	-
CFC-113	3	1	5	0.2
TOTAL	33	29	11	16

Source: Values equal the difference between virgin solvent use in Table II-2 and emissions plus water releases.

III. THE HISTORICAL REGULATORY ENVIRONMENT

There are a number of regulations that affect the industries in which solvents are used. Although these regulations do not concern hazardous waste, they have in the past and will in the future govern trends in the industry that will influence the form and amount of waste generated. In what follows, I first present a review of the health and environmental effects of each solvent. I then discuss the regulations that affect solvent use. Finally, I present two historical case studies that illustrate that solvent use--and correspondingly waste generation--is determined by non-waste regulations and that the solvents are interrelated and must be considered in concert.

HEALTH AND ENVIRONMENTAL EFFECTS

In Table III-1, I summarize and compare some important characteristics of the chlorinated solvents.

Table III-1

HEALTH AND ENVIRONMENTAL CHARACTERISTICS OF THE CHLORINATED SOLVENTS

SOLVENT	TLV (ppm)	ANIMAL CARCINOGENICITY	SMOG	POTENTIAL OZONE LAYER DEPLETION	HAZARDOUS AIR POLLUTANT
TCE	100[a]	Positive	Yes	No	Intent to List
PERC	100[a]	Positive	Yes	No	Intent to List
TCA	350	In Progress	No	Yes	-
METH	500	Positive	No	No	-
CFC-113	1000	Negative	No	Yes	-

[a] The American Conference of Governmental Industrial Hygienists (ACGIH) has recommended that TLVs be lowered to 50 ppm.

Source: ACGIH (1984); Fed. Reg. (December 23, 1985); Fed. Reg. (December 26, 1985); Quinn, et al (1986); NTP (1985).

The first column of the table gives the threshold limit value or TLV of each chemical. It is defined as the maximum allowable time-weighted average concentration to which a human may be exposed over an eight-hour working day, 40 hour work week. The higher the TLV, the higher the allowable level of exposure. CFC-113, for instance, has a TLV of 1000 ppm, the highest level allowed. PERC and TCE, on the other hand, have much lower TLVs.

The second column in Table III-1 indicates whether the solvent has been found carcinogenic in animals. TCE is classified by EPA as a possible to probable human carcinogen based on several positive mouse inhalation studies and one marginally positive rat inhalation study (Fed. Reg.; December 23, 1985).

PERC was traditionally classified as a possible human carcinogen. A recent inhalation study showed an increased incidence of liver tumors in mice and elevated levels of cell leukemia and kidney tumors in rats. Since earlier mice studies were also positive, the positive findings for rats in particular, may lead to PERC's reclassification as a probable human carcinogen (Fed Reg; December 26, 1985). EPA has reclassified the chemical as a probable human carcinogen (Call and Massouda, 1986).

TCA is presently being tested for carcinogenicity under the National Toxicology Program (NTP). It currently falls under the category of chemicals that cannot be classified according to their carcinogenic potential for humans (Oak Ridge, 1985).

A recent study performed by the NTP indicates that METH is carcinogenic in both mice and rats. An increased incidence of mammary gland tumors was observed in rats and an increased incidence of lung and liver tumors was observed in mice (NTP, 1985). EPA has reclassified the chemical as a probable human carcinogen (Call and Massouda, 1986).

A recent rat inhalation study performed by Haskell Laboratory on CFC-113 indicated that the solvent is not carcinogenic (Oak Ridge, 1985).

The third column of Table III-1 indicates whether the solvent decomposes in the lower atmosphere and forms precursors that lead to photochemical smog formation (ozone) in the lower atmosphere. All chemicals are considered to contribute to ozone in the troposphere unless specifically exempted. TCE and PERC are not exempted; TCA, METH and CFC-113 are (Fed Reg, 1983). PERCs half-life in the atmosphere is of the order of months whereas that of TCE is shorter--a matter of days.

The fourth column indicates whether the chemical potentially causes ozone layer depletion in the upper atmosphere or stratosphere. Because CFC-113 contains no hydrogen, it is not subject to attack by the hydroxyl radical in the lower atmosphere. It therefore survives intact until it reaches the stratosphere where ultraviolet light leads to decomposition. The liberated chlorine can react catalytically with the ozone. CFC-113's long atmospheric lifetime--about 86 years--and its high chlorine content make it a relatively strong potential depleter. TCA has a shorter atmospheric lifetime--about eight years--but enough of the chemical survives to be transported to the stratosphere. TCE, PERC and METH have much shorter atmospheric lifetimes so that they do not pose a potential threat to the ozone layer.

REGULATORY STATUTES

A variety of regulations apply to the solvents addressed here. In what follows, I briefly discuss the most important.

Volatile Organic Compounds

In 1977, EPA announced its "recommended policy on the control of volatile organic compounds (VOCs)." Periodically thereafter, under Section 111 of the Clean Air Act, the agency issued lists of organic compounds that are negligibly photoreactive and thus exempt from regulation to attain the National Ambient Air Quality Standards (NAAQS) under State Implementation Plans (SIPs).

Exempted VOCs include methane, ethane, METH, TCA, and eight CFCs. In 1983, EPA issued a notice to propose that PERC be exempted as well. The proposal was never made, however, and PERC therefore is still considered photochemically reactive along with TCE (Fed Reg, 1983).

A number of states have regulations designed to reduce emissions of photochemically reactive substances; they commonly require an 85 percent reduction in emissions of such substances. In the case of PERC, for instance, reductions are required for dry cleaners, solvent metal cleaners, and for fugitive emissions from other sources. Some states adopt these standards only for nonattainment areas--areas that have not achieved the ambient air quality standards for ozone--whereas others adopt them statewide.

Hazardous Air Pollutants

Under Section 112 of the Clean Air Act, EPA is required to set National Emission Standards for Hazardous Air Pollutants (NESHAP). Hazardous air pollutants are defined as air pollutants that "contribute to mortality or serious irreversible, or incapacitating reversible, illness" (Fed Reg; December 23, 1985). The list presently includes the carcinogens asbestos, beryllium, mercury, and vinyl chloride.

In December of 1985, EPA issued a Notice of intent to list TCE and PERC under Section 112 apparently because of the positive animal carcinogenicity tests on both (Fed Reg; December 23, 1985; Fed Reg; December 26, 1985). The agency intended to solicit information on the use, emissions, and health effects of the two chlorinated solvents. Although a final decision on the listing has not yet been reached, it is expected within the next two years.

Clean Water Act

Four of the chlorinated solvents--TCE, PERC, TCA, and METH--are designated under the Clean Water Act. This means that EPA is required to set water quality standards for these substances.

Comprehensive Environmental Response and Compensation Act (CERCLA)

All five chlorinated solvents considered here are listed as hazardous substances under 101(14) of CERCLA or "Superfund."

Resource Conservation and Recovery Act (RCRA)

All five chlorinated solvents are subject to the manifest system set up under RCRA. In 1984, Congress passed comprehensive amendments to RCRA specifying a ban on land disposal of virtually all untreated hazardous substances within the following six years. The first set of substances that will be banned from land disposal on November 8, 1986 are dioxins and solvents (The New RCRA, 1985).

HISTORICAL SOLVENT MARKETS

The information on the health and environmental effects of the solvents developed slowly over the last fifteen years and the increasingly encompassing regulatory regime have influenced the solvent markets. The two case studies that follow emphasize the interrelationships among the solvents and the industry response to increased regulatory scrutiny.

Case 1: TCE

For nearly three decades after World War II, TCE was the most widely used solvent for metal cleaning and degreasing. Because of its ubiquity and its mobility, the solvent is frequently found today in groundwater aquifers and drinking water wells across much of the country.

Over the last several years TCE was the subject of repeated regulatory scrutiny. In what follows, I examine the response to this scrutiny in two ways. First, I track historical production and link users' declining solvent demand to increasing regulation. Second, I follow production capacity which measures the definitive response of producers to regulation or the threat of regulation.

In Table III-2, I present the historical record of TCE domestic production. In Table III-3, I present the record of historical TCE producers and the production capacity held by each.

Table III-2

ANNUAL PRODUCTION OF TCE

(thousand metric tons)

Year	PRODUCTION
1964	168
1965	197
1966	218
1967	222
1968	235
1969	271
1970	277
1971	234
1972	194
1973	205
1974	176
1975	133
1976	143
1977	135
1978	136
1979	145
1980	121
1981	117
1982	120
1983	100
1984	86
1985	73

SOURCE: U.S. Tariff Commission Reports (1964-1973); International Trade Commission Reports (1974-1985).

TCE has an especially rich regulatory history. In 1964, there were five major TCE producers with plants in seven locations. According to the values in Table III-3, TCE capacity expanded modestly between 1964 and 1966. The Oil, Paint and Drug Reporter (later known as the Chemical Marketing Reporter) announced that 1965 was a good year for the solvent. "If trichloro is in the strongest position of all (compared with PERC and carbon tetrachloride), it is because of rising aerospace and military demand. The Vietnam War has brought stepped up procurement of it as a degreasing solvent for military equipment" (OP&DR; Feb. 28, 1966). Indeed, the values of Table III-3 reflect a 19 percent production increase between 1964 and 1966. According to the industry, a capacity expansion was predicted. "Trichloro is limited not only by the shortage of chlorine, but like methylene chloride, capacity for the solvent itself is lagging behind the market's growth" (OP&DR; Feb. 28, 1966).

Table III-3

Historical TCE Plant Capacity
(thousand metric tons)

Producer	1964	1966	1969	1972	1975	1978	1981	1983	1985*	1986*
Detrex (Ashtabula, OH)	32	36	45	-	-	-	-	-	-	-
Dow (Freeport, TX)	14	23	91	68	68	54	54	54	54	54
Dow (Plaquemine, LA)	16	18	16	-	-	-	-	-	-	-
DuPont (Niagara Falls, NY)	102	102	125	-	-	-	-	-	-	-
Hooker (Niagara Falls, NY)	20	27	27	-	-	-	-	-	-	-
Hooker (Tacoma, WA)	11	14	14	14	-	-	-	-	-	-
PPG (Barberton, OH)	20	36	-	-	-	-	-	-	-	-
PPG (Lake Charles, LA)	-	-	36	91	91	100	100	100	91	91
Diamond Shamrock (Deer Park, TX)	-	-	27	27	23	23	-	-	-	-
Ethyl (Baton Rouge, LA)	-	-	18	18	18	23	23	-	-	-
Hooker (Taft, LA)	-	-	18	27	18	18	-	-	-	-
Total	215	256	417	245	218	218	177	154	145	145

*Excludes Ethyl's 45 million pound/year plant which is on standby (probably forever)..

Note: Capacities are flexible because the equipment is also used to produce PERC.

Source: OP&DR, June 15, 1964; OP&DR, July 11, 1966; OP&DR, October 6, 1969; CMR, November 20, 1972; CMR, September 22, 1975; CMR, June 26, 1978; CMR, April 6, 1981; CMR, February 14, 1983; Farhad and Elkin, May 1985.

must offer a clear technical advantage since it is costly and inconvenient to use a solvent with a recommended TLV of 50 ppm with atmospheric emissions stringently regulated.

What lessons does the TCE case offer about substitution and regulation? First, as TCE came under increasing regulatory pressure, production declined as users substituted adequate and reasonably low-cost alternatives where they could. Second, the TCE case is one of steady erosion rather than an abrupt definitive ban. Since no regulation followed the TCE animal carcinogenicity finding in 1974, there remains an expectation that more stringent regulation may occur in the future. This is revealed in the continuing decline in TCE use. Third, the continued scrutiny of TCE for more than 15 years caused all but two of the seven producers to close their plants.

Case 2: PERC

In Table III-5, I present the historical record of PERC production capacity. This, combined with the production levels of the solvent given in Table III-6 allow some insights into the historical PERC market.

The values of Table III-6 show that PERC production increased steadily until about 1972, held constant until 1980, and went into a decline thereafter. The capacity figures of Table III-5 show a similar trend--an increase in the early years and a decline in capacity after about 1979.

In the analysis here, I wish to focus on the dry cleaning and metal cleaning industries. Accordingly, in Table III-7, I present the percentage and amount of PERC devoted to four end uses--"dry cleaning and textile processing," "industrial metal cleaning," "chemical intermediate," and "other." The use values are equal to production minus exports plus imports.

The values of Table III-7 show that PERC use in dry cleaning and textile processing declined by 23 percent over the period. Use of the solvent as a chemical intermediate increased by 84 percent. PERC is used as a precursor chemical in the manufacture of CFC-113, one of its competitors in dry cleaning and metal cleaning. Production of that solvent increased significantly over the same period as indicated in Table II-1. Use of PERC in metal cleaning declined by 41 percent over the period. Total PERC demand for the period declined by 12 percent.

Table III-5

PERC PRODUCTION CAPACITY

(thousand metric tons)

Producer	1970	1973	1976	1979	1982	1983	1986
Detrex (Astabula, Ohio)	11	-	-	-	-	-	-
Diamond Shamrock (Deer Park,TX)	45	75	75	75	75	75	75
Dow (Freeport, TX)	54	54	54	68	68	68	-
Dow (Pittsburgh, CA)	9	9	9	18	23	23	23
Dow (Plaquemine, LA)	68	68	68	54	41	41	41
DuPont (Niagara Falls, NY)	27	-	-	-	-	-	-
Ethyl (Baton Rouge, LA)	23	23	45	23	23	-	-
Hooker (Tacoma, WA)	5	-	-	-	-	-	-
Hooker (Taft, LA)	16	23	27	-	-	-	-
PPG (Lake Charles, LA)	32	91	109	91	109	109	91
Stauffer (Louisville, KY)	32	32	-	32	-	-	-
Vulcan (Geismar, LA)	50	68	68	68	68	68	68
Vulcan (Wichita, KS)	18	23	23	23	23	23	23
DuPont (Corpus Christi, TX)	-	-	-	73	73	73	73
Total[a]	390	466	478[b]	525	503	480	394

[a] Capacities can vary by as much as 60 percent depending on the relative demand for the coproducts (TCE and carbon tetrachloride).

[b] Total value of 501 thousand mt in CMR (Aug. 9, 1976) is incorrect.

Source: OP&DR (Nov. 30, 1970); CMR (Aug. 13, 1973); CMR (Aug. 9, 1976); CMR (June 18, 1979); CMR (Mar. 22, 1982); CMR (Mar. 14, 1983); CMR (Feb. 3, 1986).

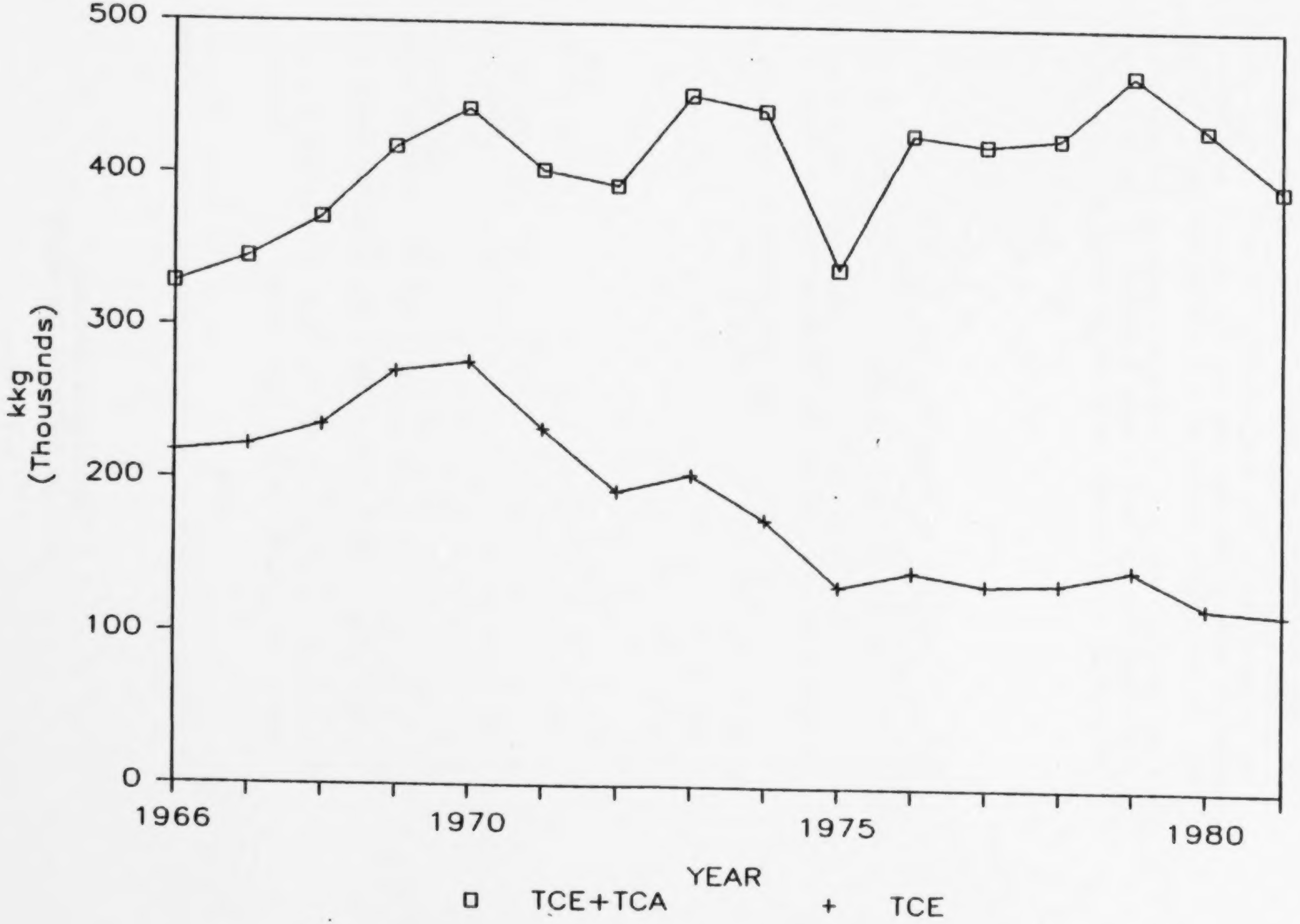

Fig. III-3--Annual Production of TCA and TCE

Table III-4

HISTORICAL TCA PLANT CAPACITY
(THOUSAND METRIC TONS)

Producer	YEAR 1968	1971	1974	1977	1982	1986
DOW (Freeport, TX)	91	136	154	204	204[a]	204[a]
Ethyl (Baton Rouge, LA)	23	18	23	--	--	--
PPG (Lake Charles, LA)	23	79	79	79	159[b]	159
Vulcan (Geismar, LA)	--	23	29	29	91	91
Total	137	256	285	312	454	454

[a] DOW has a 136 thousand metric ton per year unit on standby at Plaquemine, Louisiana which came on line in 1978.

[b] PPG has a 79 thousand metric ton per year unit on standby at Lake Charles, Louisiana.

Source: OP&DR, March 25, 1968; OP&DR, April 26, 1971; CMR, January 22, 1974; CMR, January 17, 1977; CMR, September 27, 1982; CMR, March 28, 1983; CMR, January 20, 1986.

The story of TCE is one of continued decline under increasing regulatory scrutiny. It initially appears that TCA was substituted for TCE largely in metal cleaning applications.[1] In its remaining uses, TCE

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[1] PERC may also have substituted for TCE to a small extent. The production capacity for PERC in 1969 (390 thousand mt) was approximately the same as the 1986 capacity (392 thousand mt) (OP&DR, November 30, 1970; CMR, February 3, 1986). It is not possible to sort out the offsetting effects of a decline in demand for dry cleaning (see below) and substitution for TCE.

In 1966, growth remained strong as shown by the production values of Table III-2. The industry reported that, "Recent growth has been largely spurred by the war effort...," and "Four producers not now in trichloroethylene, but in other chlorinated solvents are rumored looking at the market" (OP&DR; July 11, 1966). The values of Table III-3 show that at least two new producers-- Diamond Shamrock and Ethyl Corporation--did enter the market between 1966 and 1969. Indeed, by 1969, capacity had increased by more than 60 percent over 1966 and there were then seven producers with a total of ten plants.

In 1968, Los Angeles County adopted Rule 66 which limited emissions of TCE (OP&DR; July 3, 1968). The TCE producers and the Manufacturing Chemists Association (later the Chemical Manufacturers Association or CMA) commissioned a study to be performed by Stanford Research Institute to determine whether the solvent actually contributed to photochemical smog. Early in 1969, SRI "reported preliminary findings which seemed to clear trichloro of any serious role in pollution, but it was felt that the data were not really conclusive, and the study was extended. If the final report is favorable to trichloro, the producers, Dow among them, will press for a reversal of the Los Angeles County Rule. Orange County and the San Francisco area are expected to take the SRI findings into account in deciding on whether trichloro should be controlled as a pollutant" (OP&DR; April 21, 1969).

The SRI study showed (incorrectly, it was later determined) that TCE did not contribute to photochemical smog. In 1970, the industry reported that "Trichloro also is holding its own in its conflict with what the industry believes to be overzealous antipollution efforts on the West Coast," (OP&DR; Aug. 10, 1970). Indeed, Table III-2 shows that production of TCE continued to increase through 1970.

By 1972, the industry reported that several states had enacted legislation similar to L.A. County's Rule 66. The decline in production shown by the values of Table III-2 apparently reflected the slowdown in demand. More important perhaps, is the significant decrease in capacity--more than 60 percent--shown in Table III-3 for the period 1969 to 1972. Out of the 10 plants producing TCE in 1969, only 6 remained by the end of the period.

By 1975, industry conceded "Trichloroethylene is very photoreactive. Federal and local governments have severely restricted use and emissions of TCE in vapor degreasing plants in many areas of the country in order to reduce air pollution" (CMR; September 22, 1975). Another seminal event that signaled the final demise of TCE was a "Memorandum of alert" on TCE issued by the National Cancer Institute (NCI) in April of 1975. Preliminary findings in bioassays of the solvent indicated that it would show carcinogenic activity in mice (CMR; May 5, 1975). The test had been prompted in previous years when EPA reported that TCE and vinyl chloride--a known human carcinogen--were metabolized similarly in humans.

The values of Table III-2 illustrate the effect the smog finding and the animal study results had on the production of TCE. From the peak of 277 thousand mt in 1970, production declined more than 50 percent, to 133 thousand mt in 1975. The capacity data in Table III-3 for the period between 1972 and 1975 also show a continuing decline.

In the next decade, TCE never regained its popularity as EPA and several states placed increasingly stringent regulations on emissions of the solvent. Production continued at the lower levels as shown in Table III-2. According to Table III-3, capacity declined further as all but two producers finally exited the market. In the early 1980s the American Conference of Governmental Industrial Hygienists (ACGIH) recommended that the workplace TLV be lowered to 50 ppm from 100 ppm where it had been for more than 20 years.

As TCE, once the chlorinated solvent in highest demand, was gradually phased out of the market, what took its place? Before the smog issue was resolved in 1969, it was reported that "Opinions in the industry diverge widely on trichlor's future. Some foresee sharp encroachment by 1,1,1-trichloroethane (TCA) as capacity for the latter becomes top heavy. Others believe trichloroethylene will hang on to its existing market," (OP&DR; October 6, 1969). In 1977, the industry stated of TCA, "Conversion from trichloroethylene, especially in vapor degreasing will keep growth fairly strong," (CMR; January 17, 1977).

By 1975, the conversion was in full swing. In 1974, the industry reported that "Conversion from trichloroethylene to 1,1,1-trichloroethane to comply with air pollution standards has proceeded rapidly in solvent and degreasing applications," (CMR; January 22, 1974). A few years later, industry reported, "A gradual decline in the use of trichlor now seems inevitable. Substitution of trichlor with such alternative solvents as perchloroethylene and 1,1,1-trichloroethane is being actively pushed by some manufacturers. The pace of substitution may well be accelerated in the next several years, as at least one trichlor market is known to favor a total phasing out of trichlor in favor of alternative chlorinated solvents," (CMR; April 16, 1981). In 1983, industry claimed that "Some substitute solvents like 1,1,1-trichloroethane are said to be replacing trichloroethylene," (CMR; February 14, 1983).

In Figure III-3, I show TCE and TCA production for the 20 year period. From these data, it certainly appears on the surface at least, that TCE was largely replaced by TCA. To explore this notion more fully, I show the history of TCA's capacity in Table III-4. Comparing the values of Tables III-3 and III-4, we observe a production capacity decrease of 270 thousand mt for TCE from 1969 through 1986. We also observe an increase of about 315 thousand mt of TCA capacity from 1968 through 1986. This suggests that TCA capacity increased to fill the gap left by TCE plants that were closing.

Table III-6

ANNUAL PRODUCTION OF PERC

(thousand metric tons)

YEAR	PRODUCTION
1964	166
1965	195
1966	210
1967	242
1968	289
1969	288
1970	321
1971	320
1972	333
1973	320
1974	333
1975	308
1976	303
1977	279
1978	329
1979	351
1980	347
1981	313
1982	265
1983	248
1984	260
1985	224

Source: U.S. Tariff Commission Reports (1964-1973); International Trade Commission Reports (1974-1985).

What caused the decline in recent years in the amount of PERC used in dry cleaning and metal cleaning? The trend started in 1976 when the industry reported, "Domestic dry cleaning is on the decline," (CMR; August 9, 1976). The reason became obvious in 1979 when the industry explained, "The increasing popularity of wool blends, silks and other clothing fabrics that must be dry cleaned has shored up demand that had been undercut by wash-and-wear wardrobes." The same source indicated that, "More efficient dry-cleaning machines reduce demand," (CMR; June 18, 1979). Indeed a comparison of PERC production of 351 thousand mt in 1979 (Table III-6) with the capacity of 525 thousand mt (Table III-7) shows that significant excess capacity existed.

In 1979, amendments to the Clean Air Act required states with areas not in compliance with specified ozone levels to submit plans for meeting the standards for volatile organic compounds (VOCs). PERC was one of the chemicals specifically restricted.

Table III-7

PERC END USE ALLOCATION

Use	1978 Percent[a]	1978 Use (thousand metric tons)	1985 Percent[a]	1985 Use (thousand metric tons)
Dry Cleaning and Textile Processing	64	203	56	156
Chemical Intermediate	14	44	29	81
Industrial Metal Cleaning	16	51	11	30
Other	6	19	4	11
Total	100	317	100	278

[a] Values have been adjusted to account for exports of 29 and 10 thousand mt in 1978 and 1985 respectively, and imports of 17 and 64 thousand mt respectively.

Source: CMR (February 3, 1986); CMR (June 18, 1979).

In 1978 and 1979, OSHA developed a new carcinogen classification scheme. Around the same time the Consumer Product Safety Commission (CPSC) developed its own carcinogen policy. The first chemical to be classified by CPSC was PERC. In this light, in 1979 the industry reported that, "CPSC has clouded PERC's future by branding it a carcinogen. Growth is tied otherwise to population trends. Petroleum cleaning solvents will not replace PERC because of their flammability. Government actions, if they came would most alter PERC's future," (CMR; June 18, 1979). Sometime later, CPSC withdrew its proposal to classify PERC as a carcinogen. The action, however, may have had an effect on the market.

By 1982, PERC production had declined significantly (see Table III-6). One industry source claims that there are two reasons for the long-term decline. First, synthetic fibers replaced natural fibers in the 1970s to some extent in this country. Dry cleaning, for these garments, was no longer necessary. Second, dry cleaning and metal cleaning equipment have become more efficient and solvent losses have been reduced considerably, largely in response to the more stringent VOC regulations. Thus, demand for virgin PERC has correspondingly declined.

The Chemical Marketing Reporter seems to verify the second reason. In 1982 it claimed that, "More efficient dry-cleaning machinery, stewardship programs, and recycling steadily reduced demand for the material (PERC)," (CMR; March 22, 1982). In 1986, this theme was reiterated. "Greater recycling and less solvent emissions from dry cleaning equipment and metal cleaning machinery have gradually reduced PERC demand in these sectors. Demand for PERC in the dry cleaning and metal cleaning industry will continue to decline slowly, but gains in the F-113 businesses will largely offset this loss barring further restrictions on PERC's use," (CMR; February 3, 1986). This latter comment implies that growth in CFC-113 demand increased PERC use as an intermediate.

In general terms, metal cleaning and dry cleaning equipment for all solvents including PERC has become more conservative of solvent in recent years. In dry cleaning specifically, one reliable industry source attributes the more conservative measures partly to cost considerations but also to increased health and environmental concerns. He cited the smog regulations under Section 111 of the Clean Air Act as having lead to reduced PERC consumption. He maintained that the EPA proposal to list PERC as a hazardous air pollutant under Section 112 of the Clean Air Act and the recent positive animal carcinogenicity tests contributed to the decline in use. He claimed that dry cleaners are not only nervous about employee lawsuits from exposure to a potential carcinogen but also are concerned that there could be lawsuits from people living in the neighborhood if they later developed cancer.

The case of PERC is interesting because it illustrates that a market can decline for a host of reasons rather than because of one significant event. Production and production capacity have decreased gradually in the 1980s in response to more stringent regulations on air and water emissions.

IV. SOLVENT WASTE REGULATION

This section focuses on the response of users to regulations that govern hazardous waste generation by users of halogenated solvents. In what follows, I first summarize the regulations that affect the analyzed industries. I then identify some of the alternatives to land disposal that are presently exercised and discuss the potential for minimizing waste.

REGULATIONS ON WASTE

Two different types of provisions affect users of halogenated solvents in the analyzed industries. I deal with each in turn below.

Solvent Provisions

The 1984 Hazardous and Solid Waste Amendments (HSWA) to RCRA required EPA to phase out the land disposal of untreated waste by 1992 at the latest. The first group of wastes included dioxins and solvents; they were to be banned from land disposal in November of 1986. Unless EPA promulgated regulations in the spirit of the amendments, certain hammer provisions would become effective on that date.

In May of 1985, bulk or containerized liquid waste of any kind was prohibited from landfills. In January of 1986, EPA proposed the rule that would ban the land disposal of untreated dioxins and solvents. In terms of solvents, the proposal established the ban for all but three types of excluded waste for which treatment technology was not available.

If the final regulation takes the form of the proposed regulation, it would particularly prohibit land disposal of wastes containing more than one percent or 10,000 parts per million (ppm) by weight of solvents of certain types. These include the so-called F001 and F002 wastes. F001 specifies the spent halogenated solvents--TCE, PERC, TCA, METH and CFC-113--used in degreasing as well as their mixtures or blends, and the still bottoms from recovery of the solvents or mixtures. This waste class would affect solvents used in metal cleaning and electronics. F002 specifies the same five spent solvents (among others) and their mixtures or blends, and the still bottoms from recovery of solvents or their mixtures. The use of these solvents remains undefined in the F002 category. Consequently, it includes the PERC and CFC-113 in dry cleaning (Fed. Reg.; Jan. 14, 1986).

Users who treat their solvent wastes have the option of meeting a treatment standard rather than the limits specified above. Table IV-1 shows these treatment standards for each of the solvents of concern. It is worth noting that most generators would find it extremely difficult to meet the required treatment levels of Table IV-1.

Table IV-1

SOLVENT WASTE TREATMENT STANDARDS

(ppm)

SOLVENT	SCREENING LEVEL
TCE	0.1
PERC	0.015
TCA	2.0
METH	1.2
CFC-113	2.0

Source: Fed. Reg. (Jan. 14, 1986).

By November of 1988, the proposed regulations would exclude certain halogenated solvents from land disposal altogether unless they are treated and meet the standards specified in Table IV-1 (Fed. Reg.; Jan. 14, 1986).

Land disposal restrictions in certain states are more stringent than the Federal regulations. In California, for instance, liquid wastes containing halogenated solvents at concentrations greater than 1000 ppm have already been prohibited from land disposal (Title 22, 1985). This regulation is more stringent than the federal regulations that will go into effect in November of 1986.

Small Quantity Generator Provision

Most of the dry cleaners and some of the firms which do metal cleaning are classified as small quantity generators (SQGs) or generators of between 100 and 1,000 kilograms of hazardous waste each month. The 1984 HSWA amendments required that SQGs be brought under RCRA. The amendments also authorized EPA to regulate generators of less than 100 kilograms per month if the administrator determined it was necessary to protect human health and the environment.

In March of 1986, EPA promulgated regulations that would subject SQGs to the manifest reporting system (Fed. Reg.; March 24, 1986). In September, SQGs would be subject to all other RCRA regulations.

MANAGEMENT OPTIONS FOR WASTE

Alternatives to land disposal of halogenated solvents are numerous; they fall into two generic categories. The first type of option reduces the use of the solvents and therefore the amount of waste generated. One such option is substitution of aqueous based cleaners for solvents. In electronics, for instance, printed circuit board degreasing can be performed with CFC-113/alcohol blends or with deionized water (Morrison and Wolf, 1985). Another options is the use of carbon adsorption for the capture of vapors. Desorption--usually with steam--regenerates the solvent for reuse reducing the requirement for virgin solvent. A third option is reclamation of spent solvent wastes for reuse in place of virgin solvent. In-house distillation or use of an external reclamation firm can yield purified solvent for reuse.

The second type of option focuses on dealing with the waste or still bottoms after they are generated. These options include various types of thermal destruction like rotary kilns and cement kilns for sludges, and fluidized beds for spent liquid wastes.

An option that offers substantial leverage in minimizing the amount of solvent waste generated in the first place is reclamation. This option is technically appropriate for each of the industries considered here. In what follows, I first focus on solvent reclamation in general and then present two case studies where firms have adopted reclamation in response to the hazardous waste regulatory regime.

Reclamation Potential

In electronics, vapor degreasing, and cold cleaning, the soils removed in the cleaning process accumulate in the equipment during cleaning operations. Eventually, the solvent becomes too contaminated for further use and it must be either reclaimed or discarded. In the dry cleaning industry users generate two types of waste. The first is a still bottom that remains from distillation. The second is either a standard cartridge or adsorptive filter that contains a solvent residue.

Solvent is frequently reclaimed for reuse by the user. The most commonly employed technique is distillation which separates a volatile solvent from the higher boiling contaminants. Some users contract with an external reclamation firm that may use either distillation or thin film evaporation which is especially appropriate for sludges. Some users reclaim only in-house; some reclaim only externally; and some reclaim both in-house and externally.

According to an EPA survey, in 1981 114.3 million gallons of halogenated solvent waste were reclaimed on-site for reuse and 58 million gallons were reclaimed off-site. These data exclude SQGs which suggests dry cleaning waste is not included (EPA, 1984). An EPA official believes this is a lower bound to the amount of solvent actually reclaimed. For the most part, this reclaimed solvent is likely to be reused in three of the sectors analyzed here--cold cleaning, vapor degreasing, and, to a smaller extent, electronics. Because many electronics applications require a high level of purity, some users are reluctant to chance the use of reclaimed solvent.

Converting the reclaimed solvent to a weight suggests that 621 thousand mt and 316 thousand mt[1] of solvent were reclaimed in-house and externally respectively.[2] These values can be compared with virgin demand which amounted to 472 thousand mt. These figures imply that use of reclaimed solvent is about twice that of virgin solvent. Although at first, this appears startling, it is reasonable to assume that virgin solvent will be reclaimed over and over many times in a particular year. It is therefore not unexpected that use of reclaimed solvent exceeds that of virgin solvent.

The potential for reclamation is much higher. One reclaimer indicates that customers commonly send spent solvent for reclamation every six weeks or two months. This suggests that the virgin solvent placed in a cleaning tank at the beginning of a particular year could be reclaimed and reused six to eight times during that year. Thus, the potential for external reclamation alone is at least six times that of virgin use or about 2.8 million metric tons. This is some nine times higher than the amount of solvent presently reclaimed externally.

Case 1: Metal Cleaning

The experiences in coping with the increased regulatory regime are perhaps typified by one California firm that does metal cleaning. This firm has a history of converting from one solvent to another. In the 1960s, the firm used TCE which it still considers the best solvent. When rule 66 was passed in Los Angeles restricting emissions of TCE, the company converted to PERC. Somewhat later, when PERC came under scrutiny as a photochemical smog contributor, the firm purchase a carbon adsorber to minimize emissions. In spite of this effort, they were unable to meet the PERC emission requirements. The firm converted once again--this time to TCA.

The conversion offered a benefit and a disadvantage. The firm's solvent use declined but the carbon adsorber could not be used with TCA. Steam is used in the desorption step and the TCA readily hydrolyzes. Over the years, the company tried to convert to deionized water but it did not have the required cleaning capability. They also investigated but rejected the use of water and detergent in ultrasonic cleaning.

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[1] The reclaimed solvent probably contains contaminants at a level of roughly 15 percent. This should be subtracted from the values. It is offset, however, by the fact that solvent use increased by some 19 percent between 1981 and 1984.

[2] The average density of the reclaimed solvent is assumed to be 12 pounds per gallon.

This firm has a distillation unit which is used to continuously reclaim solvent from the degreaser. A few years ago, in response to the waste regulations, the company contracted with an external reclaimer. They send their spent solvent for recycle every 6 weeks to two months and receive back the reclaimed solvent for reuse.

By using the external reclaimer, the firm avoids the problem of sludge disposal. They must still deal with the still bottoms generated by their in-house still however. These still bottoms contain 500 ppm of TCA. In California, the allowed level of halogenated solvent in still bottoms is 1,000 ppm, so the firm uses land disposal. They are not concerned with the Federal regulation that will go into effect in November of 1986 because the allowed solvent concentration under that statute is much higher than that in the California regulation.

The firm is anxious to avoid land disposal in the future for two reasons. First, they are wary of liability. Second, they are anticipating the 1988 Federal regulation that requires TCA to be treated to a 2 ppm screening level. In this light, they are investigating two alternatives. The company will try to air strip its still bottoms to achieve the 2 ppm level. Air stripping is perfectly legal because it is not considered a treatment technique. If that fails, they will try to contract with an incinerator to destroy their sludge.

This case study is interesting because it illustrates the response of a firm to increasing regulations. Statutes addressing photochemical smog caused them to convert to a new solvent twice. Over the years, this company has reduced its requirement for virgin solvent by adopting both in-house and external reclamation. This has, in turn, reduced the amount of waste they generate. The availability of experienced reclaimers offers this user a very attractive market solution for complying with waste regulations.

Case 2: Dry Cleaning

Before May of 1986, dry cleaners who generated less than 1,000 kilograms of waste each month were not subject ot hazardous waste regulations. These dry cleaners likely disposed of their waste in municipal landfills. Dry cleaners whose waste exceeded 1,000 kilograms per month were subject to regulations; most of them probably used land disposal.

After the regulations on SQGs go into effect in September of 1986, dry cleaners could still use land disposal. An official of the International Fabricare Institute (IFI) estimates the cost to an average dry cleaner for land disposal at $5,000 annually. A significant disadvantage is that after November, the dry cleaning filtration residues and still bottoms cannot be disposed of in landfills without a significant reduction of halogenated organics in the waste. In California where the stricter regulation has already become effective, land disposal is already restricted.

A second option for dry cleaners is to incinerate the waste. The same IFI representative estimates the cost at between $8,000 and $13,000 annually depending on the cost of transportation. In fact, one group of about 300 dry cleaners in Massachusetts is presently exercising this option at an annual cost to each dry cleaner of $8,800.

A third option--the one that has already been chosen by most dry cleaners--is to use the services of a reclamation firm. Such firms pick up dry cleaners' waste on a regular schedule and fill out the manifest. They transport the spent cartridge filters and still bottoms to central processing facilities where they reclaim the PERC.[3] Some of the reclaimed PERC is sold back into the metal cleaning industry; some is sold back to dry cleaners.

The reclamation option is presently more economic than land disposal or incineration. The cost of the service to the average dry cleaner is about $900 per year. Furthermore, by using the services of the reclaimer, the dry cleaner can sidestep the disposal problem. The reclaimer must then deal with the sludges generated in the purification processes. Such sludges are presently disposed of either in landfills or are incinerated.

One reclaimer has stated that the impending November land disposal regulations will not affect his business. The sludges that result from the reclaiming operation contain perhaps 50 ppm of PERC which will still meet the proposed November standards of one percent or 10,000 ppm. This concentration of PERC will not meet the 1988 proposed standards, however, and the reclaimer is exploring future options for incineration.

A second reclaimer currently sends some of his waste to landfills and some to a cement kiln that will accept waste with less than three percent halogenated organics. The November 1986 regulations will not affect his present practices but the 1988 ban may force him to rely exclusively on cement kiln destruction.

Reclaimers have provided a mechanism for bringing a significant fraction of dry cleaning establishments under the RCRA rubric. The case of dry cleaning illustrates that regulation can encourage innovative market solutions.

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[3] The amount of CFC-113 waste is so small that it is probably not reclaimed.

V. CONCLUSION

The analysis presented here emphasizes three major themes. First, the halogenated solvents are an interrelated set of chemicals and regulations affecting any of them may affect one or more of the others. Second, to place in context the regulations on hazardous waste, the entire life cycle of solvent use must be considered. Third, the historical response of the industries using these solvents to non-waste regulations can shed light on the current efforts to identify mechanisms for moving away from land disposal.

The five halogenated solvents have a variety of health and environmental problems. They are regulated under a range of federal and state statutes. The case study on TCA highlights the interactions among the members of this class of solvents when one of them is regulated or placed under regulatory scrutiny. The case study on PERC illustrates the influence of market effects and regulation on reducing solvent use.

Industry is seeking alternatives to land disposal because of more stringent regulations, because of the fear of future liability and because disposal sites are closing. One option that can reduce reliance on land disposal is reclamation and reuse of solvent. Users are beginning to adopt reclamation as a method of reducing or avoiding the generation of waste requiring disposal.

The regulations on solvent hazardous waste have been implemented in an atmosphere of increasing regulatory scrutiny during the last decade. The response of one user was to substitute to a less regulated solvent twice during the 1970s and to adopt reclamation to reduce virgin use of the solvent. This in turn reduced the amount of waste the firm generated. The response of another set of firms only recently subject to RCRA was also to implement reclamation. The private sector--the reclamation firms--offer a convenient mechanism to users to prevent or reduce the amount of waste they generate.

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UV-OXIDATION SYSTEMS FOR CONTROLLING CHLORINATED AND OTHER SOLVENTS IN WATER AND AIR

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ABSTRACT

Ultrox International manufactures and markets systems for destroying halogenated and other solvents in either water or air.

Halogen solvents in air are decomposed and oxidized by passing the contaminated air through a heterogeneous, proprietary catalyst bed. The catalyst adsorbs the halogen compounds on its surface and allows either ozone, UV or oxygen in the air to strip and oxidize the halogen compounds to halides, carbon dioxide, and water.

Halogen compounds in water are detoxified by means of a non-venting, flow-through treatment tank. Ozone-in-air is diffused through the water in the tank in conjunction with UV radiation to effect oxidation in the water. Five to ten percent of the volatile organics are stripped off during oxidation. The heterogeneous catalyst bed is used to detoxify the stripped-off compounds. The decontaminated air then recirculates back to the non-venting treatment tank to again strip or oxidize more halogen compounds in the entering water stream.

Tests to date show that these systems can be used for a broad spectrum of halogenated solvents including TCE, PCE, CCl_4, $CHCl_3$, TCA, VCM, and DCE.

Ultrox International (UI) was formed two years ago to market and manufacture systems to decompose and oxidize organic compounds in water and air. UI recently acquired Westgate Research Corporation, the developer of a number of UV-oxidation and catalytic processes for removing or decomposing air and water pollutants. Westgate had been in the R & D business for 12 years.

In this paper, the chemistry of UV-oxidation of halogenated compounds will be discussed along with Ultrox's latest developments for destroying volatile halogenated solvents in water and air.

Westgate had conducted several laboratory study programs on the chemistry of UV-ozone oxidation of refractory organic compounds in water under the sponsorship of the National Science Foundation and the Office of Water Research of the Department of the Interior.[1,2,3] These studies included the chemistry of UV/O_3 oxidation of chlorinated compounds. In these studies it was postulated that the oxidation of chlorobenzene proceeds as shown in Figure 5.

Initially a hydroxyl group is added to the benzene ring to produce a chlorophenol. The chlorine can be removed from the ring structure at any of the intermediate steps. Sequentially the ring is broken and the predominant end products are oxalic and formic acids. It appears from work on phenolic compounds that the dechlorinated end products can be expected to be non-toxic and biodegradable. In the case of chlorinated alkanes and alkenes, the intermediates are aldehydes, alcohols and acids. Continued UV-oxidation of the intermediate products will produce carbon dioxide and water.

For example, as part of our studies for the National Science Foundation, we conducted a series of experiments where O_3, UV/O_3, and UV alone were used to obtain rates of decomposition for representative chlorinated organic compounds in water. The experimental conditions were: 30-35 mg/min @ 4 wt% O_3 in O_2, 3 liter reactor with one 40W lamp, and detection by Electron Capture-GLC. Figures 1 through 4 demonstrate the rate of degradation of hexachlorobenzene (HCB),1,2,-dibromo,3-chloropropane (DBCP), pentachlorophenol (PCP), and Gamma-1,2,3,4,5,6-hexachlorocyclohexane (lindane). Ozone alone was only effective in the oxidation of PCP, reducing its concentration from 50 to 6.5 ug/l in 15 minutes. On the other hand, the UV/O_3 process readily oxidized each of the chlorinated hydrocarbons. PCP was reduced from 50 to 1 ug/l in 5 minutes. Similarly, lindane and DBCP were oxidized to 1 ug/l in 15 minutes and 30 minutes, while HCB was reduced to 1.5 ug/l in 60 minutes.

The UV/O_3 process has been used to treat other chlorinated compounds in water in the laboratory, pilot plants, and full-scale equipment. For example, model compounds representing different types of polychlorinated organics were oxidized in the laboratory with ozone in the presence and in the absence of UV light. The concentration of the chloride ions being formed was then measured.[4] The rate of the chloride ion formation from 2,3-dichloropropanol, tetrachlorophthalic acid, 2,2,2-trichloroethanol, and ethylene dichloride during ozonation and UV-ozonation are shown in Figures 6, 7, 8, and 9 respectively. The quantity of chloride ions formed when using ozone by itself was below the limit of detection. In comparison, during UV-ozonation all the C-Cl bonds were rapidly broken to produce 100% of the theoretically possible chloride ion concentration.

Both pilot plant and full-scale systems have been developed which are designed to treat industrial wastewaters, leachates, and contaminated ground waters. Photos of two reaction systems are shown in Figure 10 and 11 which can treat using either UV-ozone or UV-hydrogen peroxide from up to 100 gpm in the smaller systems (Model P-675) to up to 500 gpm in the larger systems (Model F-4800).

In the past two years, another system has been developed for decomposing and oxidizing volatile halogenated compounds in both water and in air. This system passes the water through a compartmentalized reaction tank containing a number of long-life UV lamps. The ultraviolet light energizes the internal structure of the organic compounds in the presence of ozone to produce a rapid oxidation of the halocarbons, converting them to carbon dioxide and water. The "halo" part of the compounds is changed to chloride or bromide ions.

About 5 to 10 percent of the halocarbons escape from the water with the outgoing gas before being oxidized. A non-venting system with a catalytic decomposer (D-TOX) is used to capture and destroy these escaping volatile organics (see Figure 12). The D-TOX catalyst is the "breakthrough" feature of this system. Any residual by-products are returned to the water in the reactor. They are then converted to carbon dioxide and water. The air is then passed through a catalytic ozone decomposing unit which destroys any remaining ozone in the air prior to sending it back to the ozone generator.

In this system, no contaminated air is vented to the atmosphere. The process has the advantages of a low-profile, economy of operation, no air pollution, a strong oxidizing regime, and once-through operation without regeneration cycles.

The catalytic D-TOX unit by itself can cost-effectively control air pollution on existing stripping towers and other chlorinated solvent generators as an end of the pipe system.

Demonstrations of the non-venting UV/O_3 system have been conducted in Pasadena, California, Fort Dix, New Jersey, and a number of industrial sites in Southern California. In addition, a demonstration of the effectiveness of the D-TOX catalytic decomposition/oxidation system designed to be used for air stripping towers has been completed at Radian Corporation under the sponsorship in part of the EPA and the Air Force. Summaries of the results of these demonstrations are shown in Tables 1 through 3.

The Pasadena Water & Power demonstration took place at a well site on the northern edge of Pasadena in July, 1984. The water to be treated was pumped from a non-working well, since the water was contaminated with 16 ug/l of TCE and 10 ug/l of CCl_4. As shown in Table 1, the non-venting system reduced both well below California's action standards. During this demonstration, engineers from the California South Coast Air Quality Management District conducted a series of air analyses on the non-venting system to determine if any air pollutants including chlorinated compounds were effusing from the system. No air pollutants were detected in the ambient air throughout the demonstration.

Projected operating and maintenance (O & M) and capital costs for cleaning up these very low concentrations of solvents in water for a full-scale 1,000 gallon per minute system for this well were derived from the demonstration tests. As Table 1 shows, the O & M costs are under 13 cents per 1,000 gallons of water treated, and the projected capital cost for the Pasadena equipment is in the $350,000 range--not installed.

Table 2 indicates the results of the Fort Dix demonstration using the non-venting system on an abandoned landfill site leachate. As shown in this table, the leachate contained methylene chloride, 1,1-dichloroethane, trichloroethylene, 1,1,1-trichloroethane, benzene, and toluene. All of these compounds were reduced below detectable limits with the exception of the 1,1-dichloroethane which was reduced to 6 ug/l--just 1 ug/l above the less than 5 ug/l detectable limit.

This leachate contained other background organics which were non-toxic, but which were oxidized along with the toxic compounds. The leachate also had a 24 mg/l iron content. These two factors increased the demand for a higher than normal usage of ozone. By proper pretreatment of the leachate for the removal of iron, the full-scale treatment cost will be reduced considerably from 0.7 cents per gallon as shown in Table 2.

Table 3 describes the results of using a pilot D-TOX air pollution, chlorinated hydrocarbon control system in a simulated air stream from a stripping tower. The simulated air stream was composed of compressed air flowing at 16 acfm and injected with 2.0 ppmv of trichloroethylene (TCE) and 4.8 ppmv of dichloroethylene (DCE). This air was then passed through the

D-TOX system. A very low flow (approx. 0.3 scfm) of ozone in air was simultaneously injected into the catalytic bed. The results of these demonstration tests were dramatic, since neither the TCE nor the DCE could be detected (less than 0.3 ppmv) in the effluent air stream.

Time did not allow optimization testing to be conducted to obtain minimum O & M and capital costs. However, non-optimized projections are given in Table 3 for a 2,500 scfm air pollution catalytic system for a stripping tower which accommodates 700,000 gallons per day of water. The tower is designed to accommodate water with TCE and DCE concentrations which will produce the same TCE and DCE air concentrations in the demonstration program. The tower will be designed for an air to water ratio of 40:1.

On the basis of volume of water treated, the additional O & M cost per 1000 gallons of water treated is 16.5 cents. The uninstalled cost for the catalytic system is estimated to be $115,000. Both costs are likely to be significantly reduced once optimization is completed.

Conclusions

The clean up of chlorinated solvents has been demonstrated in both water and air on a pilot scale using new catalytic concepts. These catalytic systems are once-through processes, and no high temperature incineration is used and no regeneration or disposal of adsorbents are required. An actual water supply and a leachate source were used in the water clean-up demonstration programs. The air test on a pilot scale used a simulated off-gas as would be generated from an air/water stripping tower. Further research is underway using a small air/water stripping tower for treating solvent contaminated ground water. It is anticipated that full-scale commercial systems based upon these new concepts will be installed within the next two years.

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3. Leitis, E., Zeff, J. D., and Smith, M. M., "Chemistry and Application of Ozone and Ozone/UV Light for Water Reuse-II," Final Technical Report on research done under Contract No. OWRT 14-34-0001-1436 for U.S. Department of the Interior, Bureau of Reclamation, June, 1983.

4. Leitis, E., et al, "The Chemistry of Ozone and Ozone/UV Light for Water Reuse," Water Reuse Symposium II, August 23-28, 1981, Washington, D. C. Proceedings, Vol. 2, AWWA Research Foundation, Denver, CO.

Fig. 1

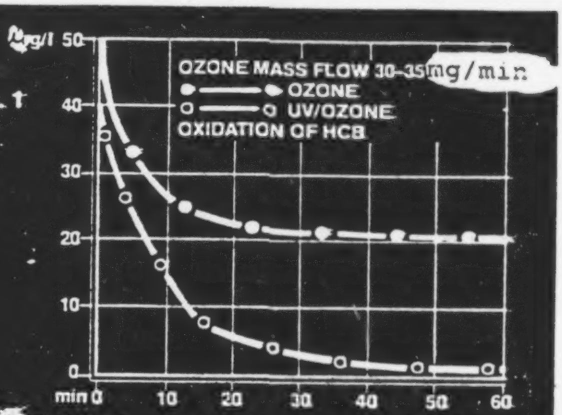


Fig. 2

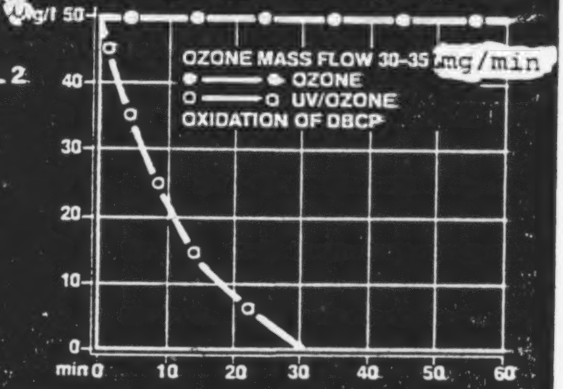


Fig. 3

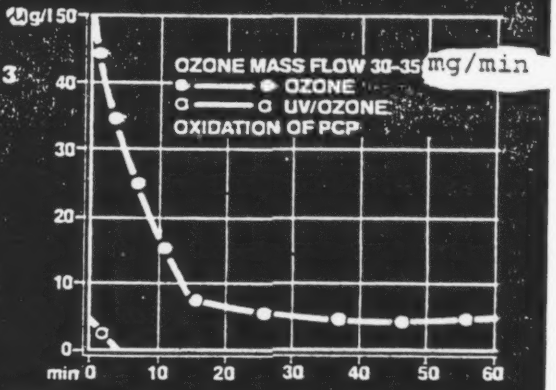
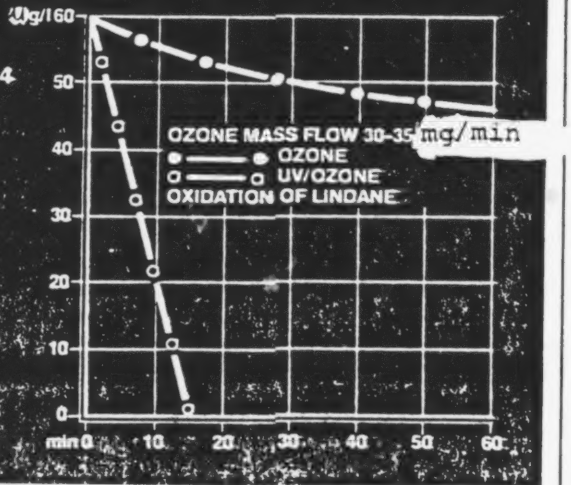


Fig. 4



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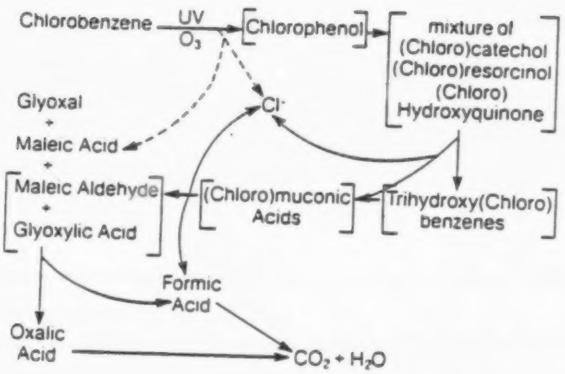
Chlorobenzene
UV
O₃
Chlorophenol
mixture of
(Chloro)catechol
(Chloro)resorcinol
(Chloro)
Hydroxyquinone
Cl⁻
Glyoxal
+
Maleic Acid
+
Maleic Aldehyde
+
Glyoxylic Acid
(Chloro)muconic
Acids
Trihydroxy(Chloro)
benzenes
Formic
Acid
Oxalic
Acid
CO₂ + H₂O

Figure 5

Proposed Reaction Pathways of the UV/O_3 Oxidation of Chlorobenzene

FORMATION OF CHLORIDE IONS FROM $CH_2ClCH_2ClCH_2OH$

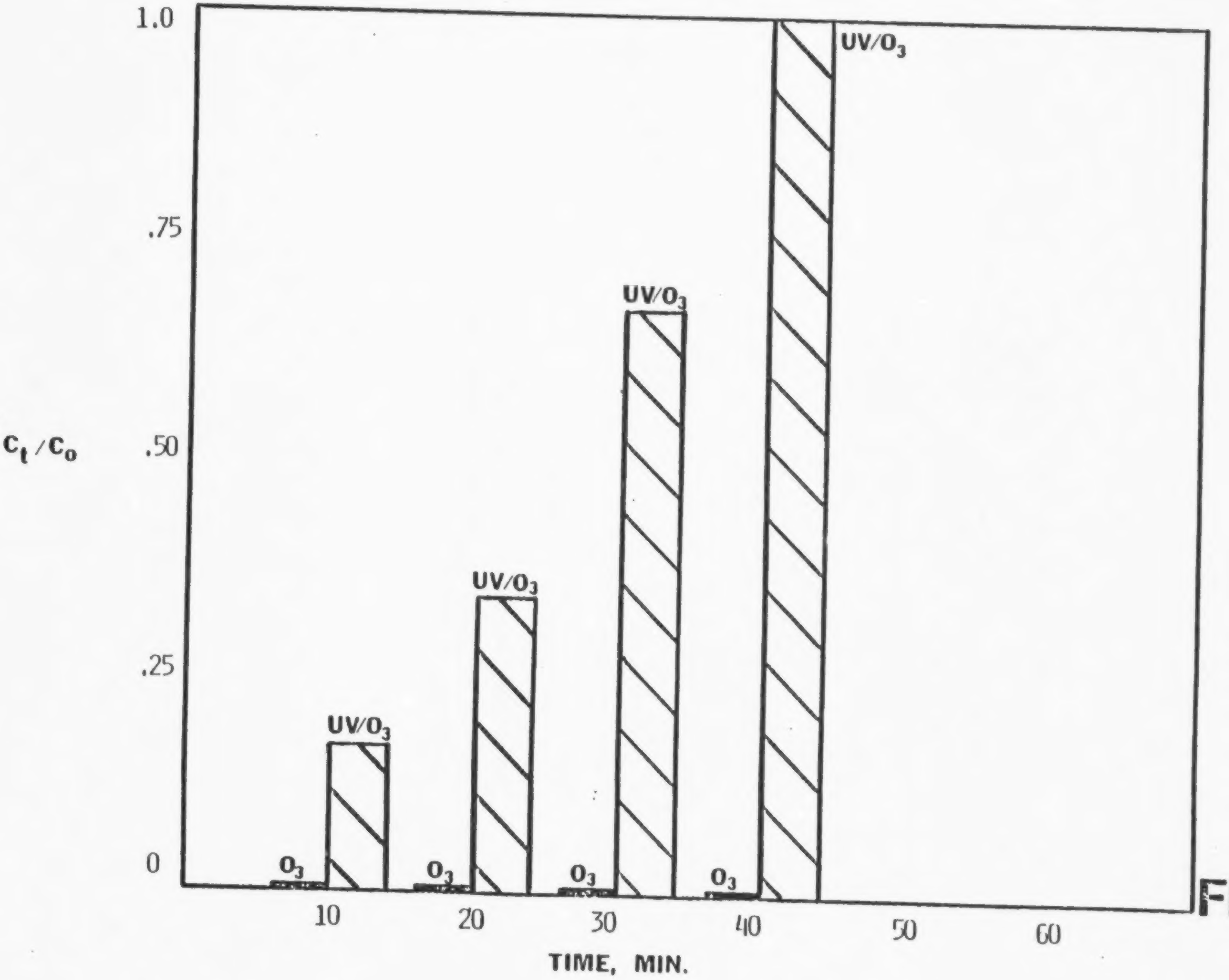

FIGURE 6

FORMATION OF CHLORIDE IONS FROM TETRACHLOROPHTHALIC ACID

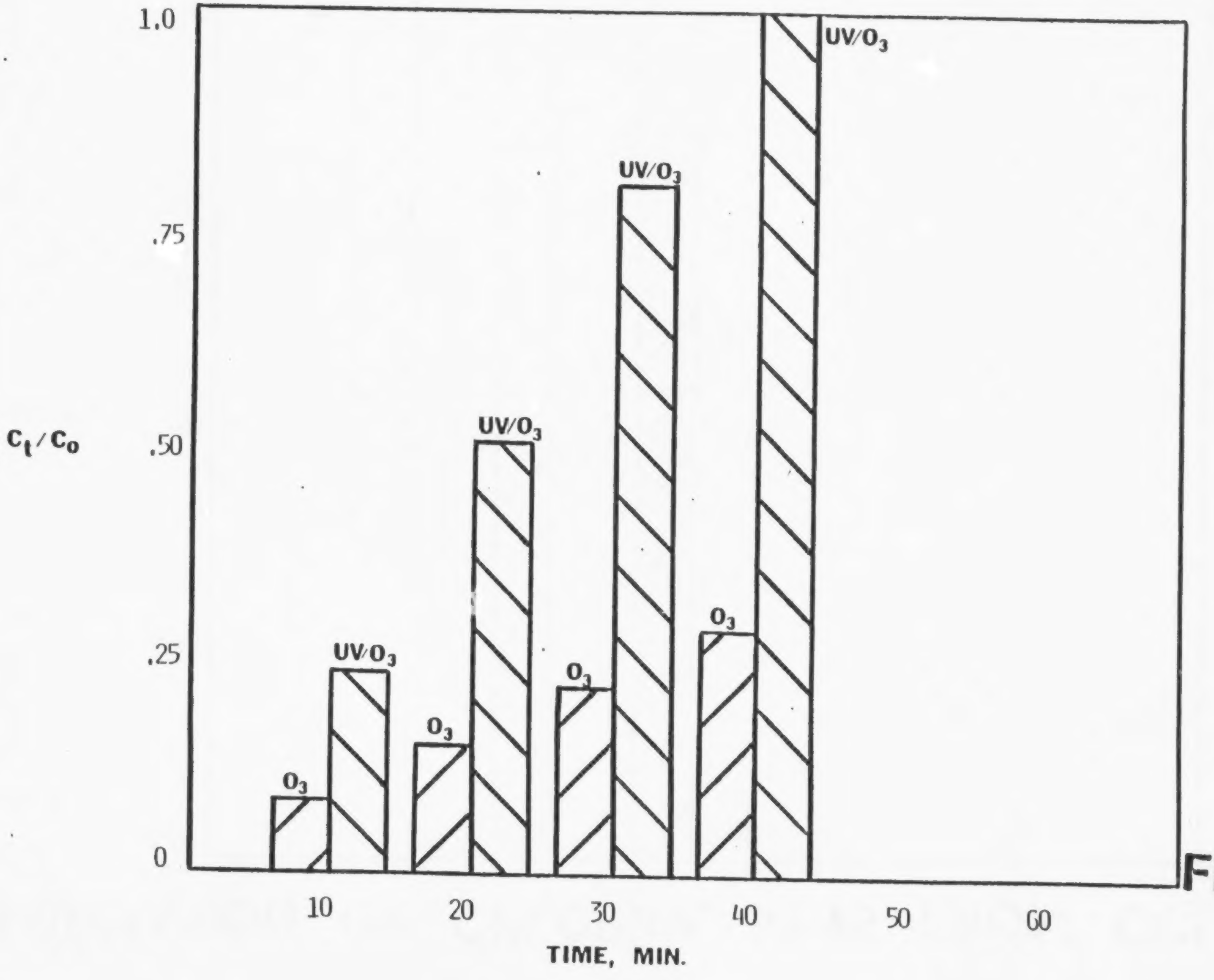

FIGURE 7

FORMATION OF CHLORIDE IONS FROM CCl_3CH_2OH

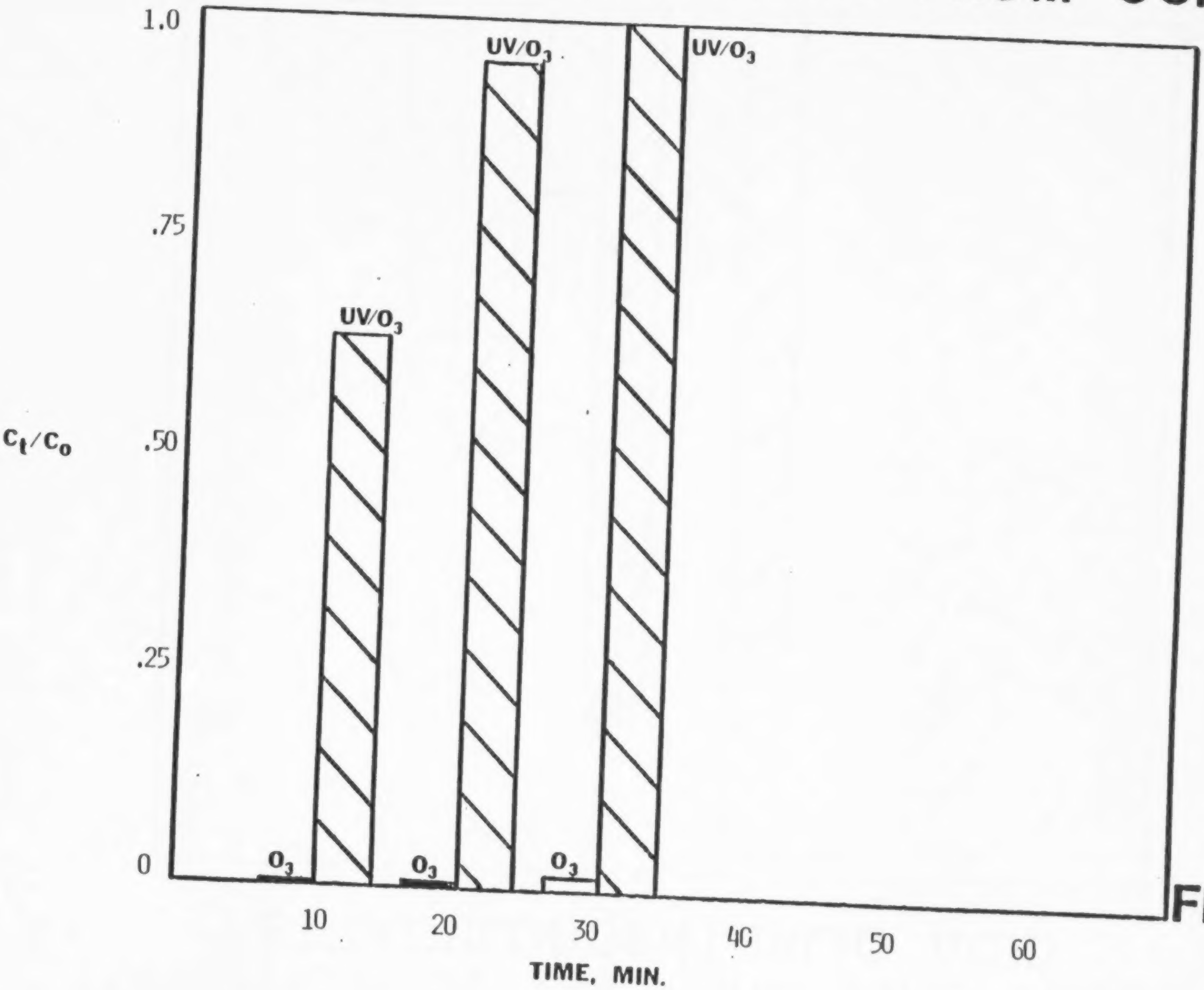

FIGURE 8

FORMATION OF CHLORIDE IONS FROM CH_2ClCH_2Cl

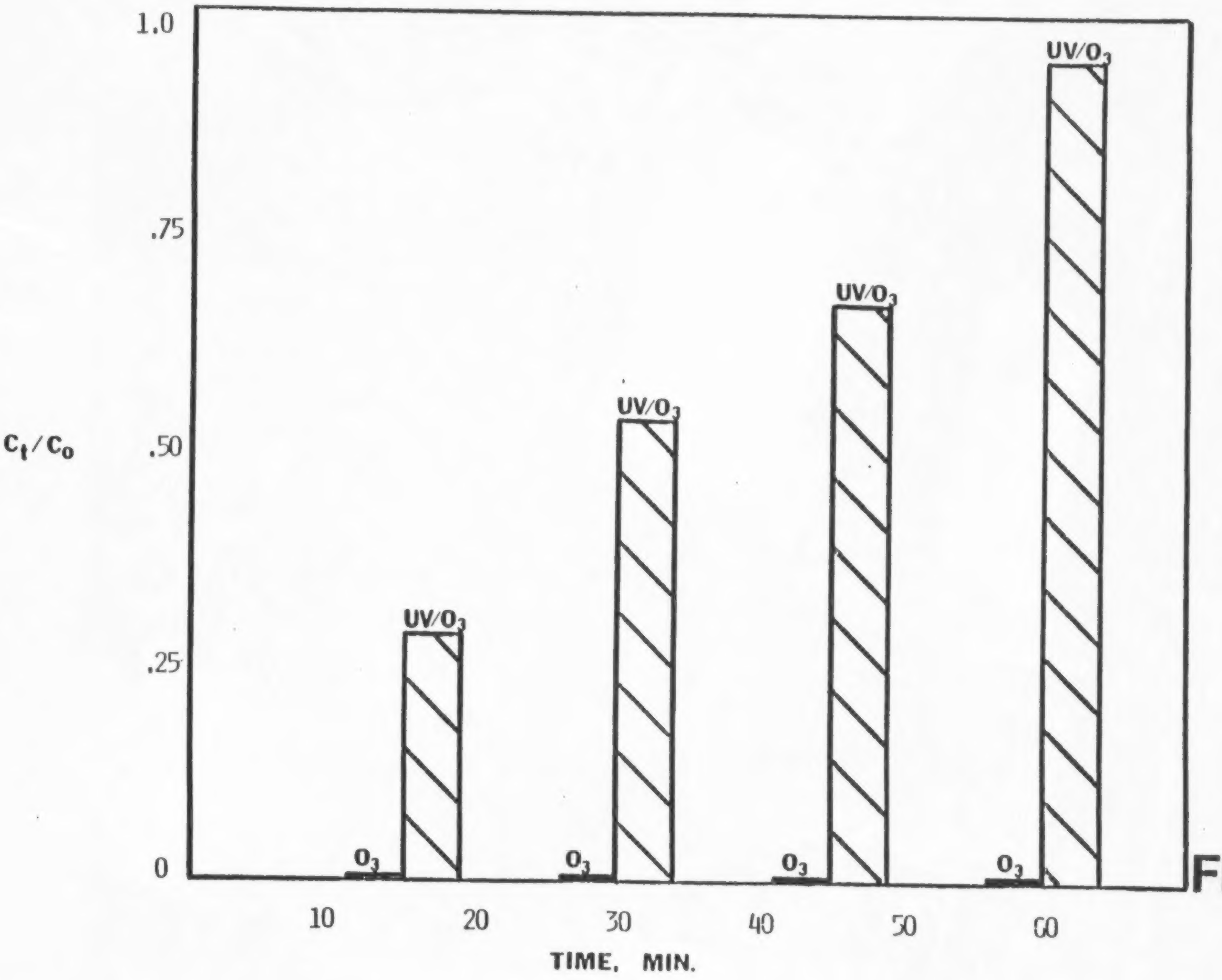

FIGURE 9

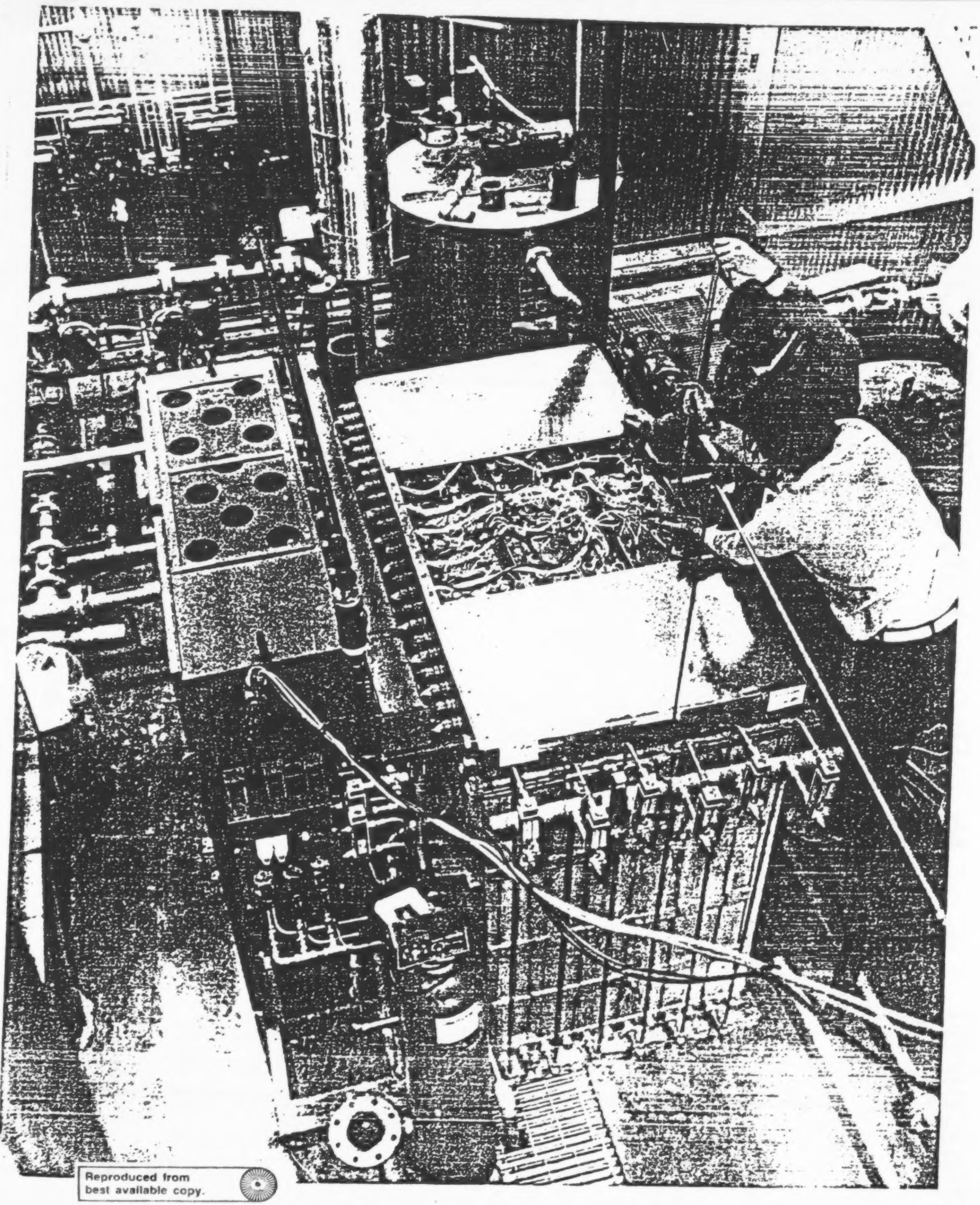

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Figure 10

Model P-675 Pilot Plant

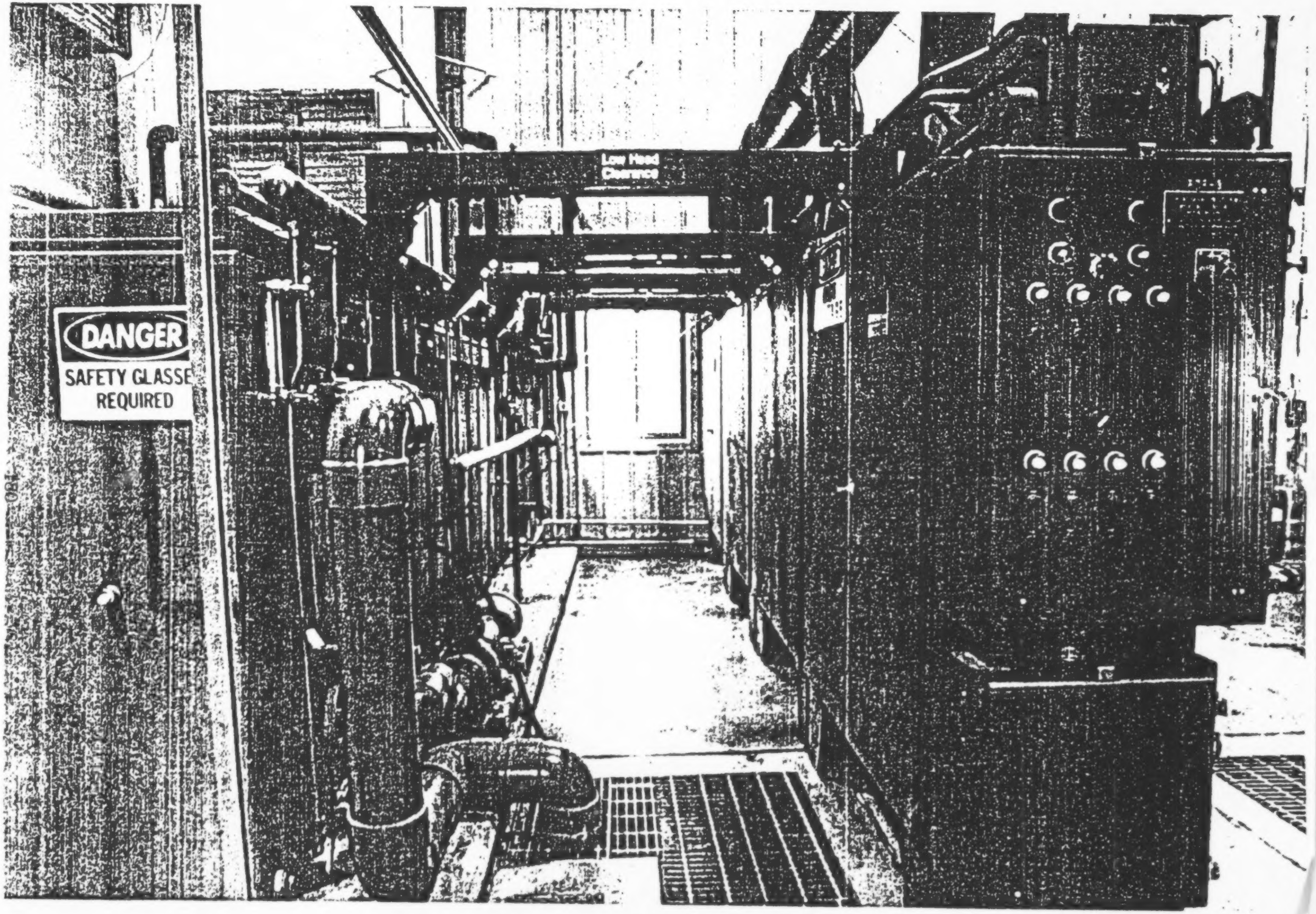
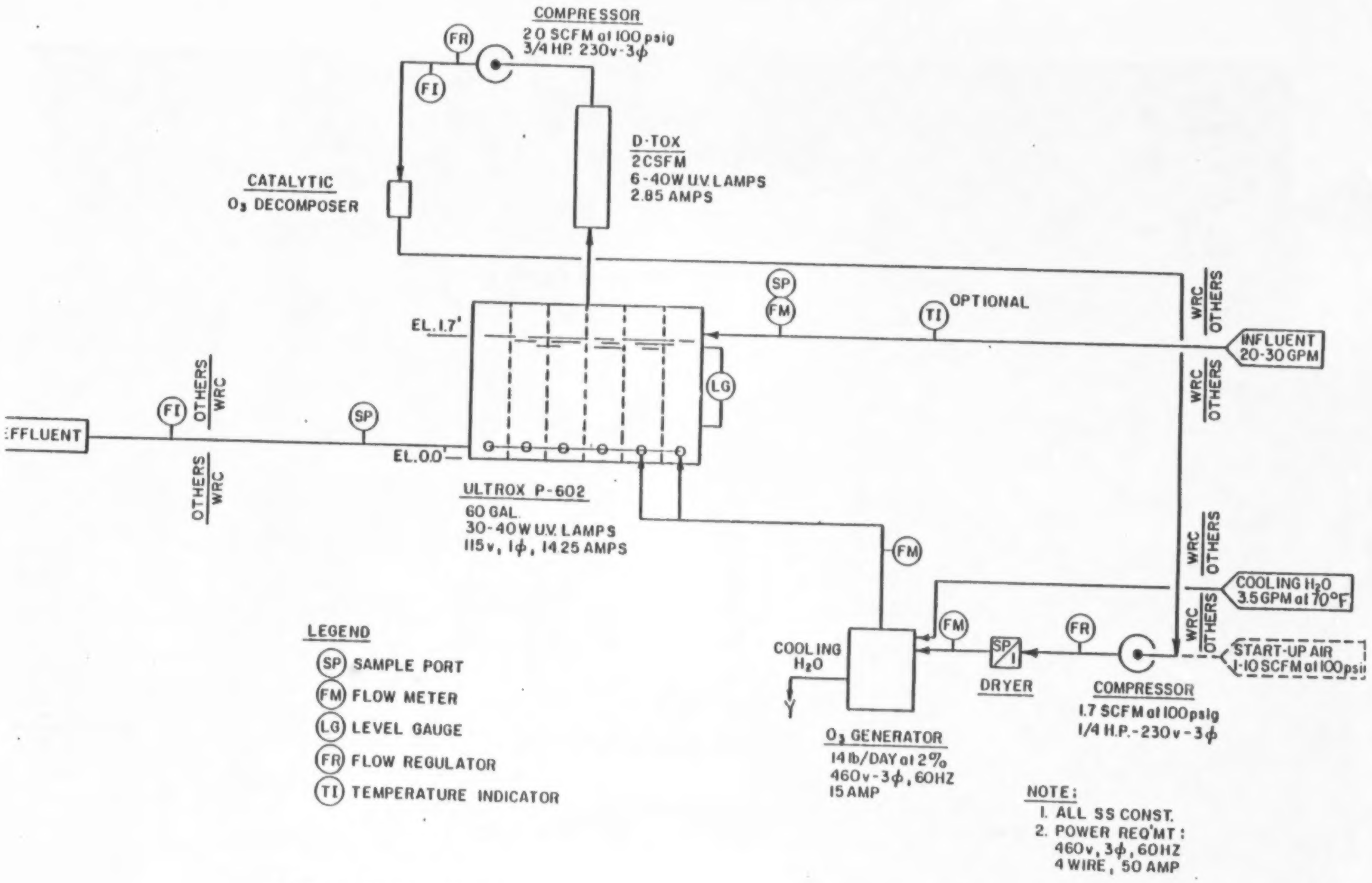
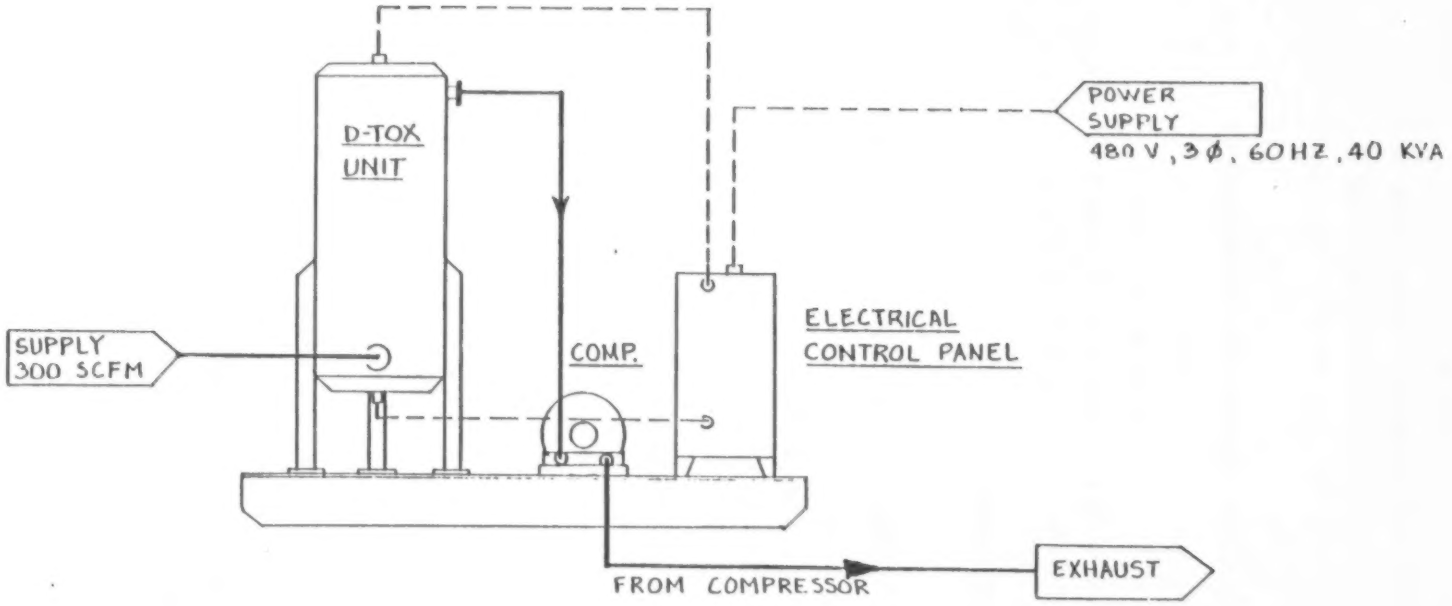

Low Head Clearance
DANGER
SAFETY GLASSE
REQUIRED

Figure 11
Model F4800 UV-Oxidation System


COMPRESSOR
2.0 SCFM at 100 psig
3/4 HP. 230v-3φ
FR
FI
CATALYTIC
O₃ DECOMPOSER
D-TOX
2CSFM
6-40W UV. LAMPS
2.85 AMPS
SP
FM
TI
OPTIONAL
WRC
OTHERS
INFLUENT
20-30 GPM
EL. 1.7'
LG
EFFLUENT
FI
OTHERS
WRC
SP
EL. 0.0'
OTHERS
WRC
ULTROX P-602
60 GAL.
30-40W UV. LAMPS
115v, 1φ, 14.25 AMPS
WRC
OTHERS
WRC
OTHERS
FM
COOLING H₂O
3.5 GPM at 70°F
WRC
OTHERS
FM
FR
START-UP AIR
1-10 SCFM at 100psi
COOLING
H₂O
SP
DRYER
COMPRESSOR
1.7 SCFM at 100 psig
1/4 H.P.-230v-3φ
O₃ GENERATOR
14 lb/DAY at 2%
460v-3φ, 60HZ
15 AMP
LEGEND
SP SAMPLE PORT
FM FLOW METER
LG LEVEL GAUGE
FR FLOW REGULATOR
TI TEMPERATURE INDICATOR
NOTE:
1. ALL SS CONST.
2. POWER REQ'MT:
460v, 3φ, 60HZ
4 WIRE, 50 AMP

NON-VENTING HALOCARBON TREATMENT SYSTEM

Figure 12


D-TOX
UNIT
SUPPLY
300 SCFM
COMP.
ELECTRICAL
CONTROL PANEL
POWER
SUPPLY
480 V, 3 Ø, 60 HZ, 40 KVA
FROM COMPRESSOR
EXHAUST

NOTE : UNIT OVERALL DIMENSION
6' × 3' × 7' (L•W•H)

300 SCFM D-TOX SYSTEM
FOR AIR STRIPPING TOWER

Figure 13

Table 1
Results of Pasadena Water and Power Demonstration and Projections for 1,000 Gallon per Minute Equipment

Non-Venting Pilot Plant Operating Parameters:

Water Flow Rate:	20 GPM
Ozone Dosage:	3 mg/L H_2O/min
UV Dosage, Reactor:	6.5 W/L H_2O/min
UV Dosage, D-TOX:	1.2 W/L H_2O/min

Pilot Plant Performance:

Principal Contaminants in Water	Average Conc. (μg/l) Influent	Average Conc. (μg/l) Effluent
trichloroethylene (TCE)	16	0.4
tetrachloroethylene (PCE)	1.3	N.D.
carbon tetrachloride (CCl_4)	10	3.1

Projected Operating & Maintenance Costs for 1000 GPM* System - Assumes $0.075/KWH and replacement of UV lamps every 15 months:

	$/1000 gal
Ozone Power Cost	0.014
UV Power Cost	0.036
Maintenance	0.025
Monitoring Labor	0.052
Total:	$0.127

* Does not include equipment amortization

Projected Capital Equipment Price for 1,000 GPM System (Not Installed):

$350,000. (Add 10-15% for installation)

Table 2

Results of Fort Dix Demonstration and Projections for 50,000 GPD Equipment

Non-Venting Pilot Plant Operating Parameters:

Water Flow Rate:	1 GPM
Ozone Dosage:	140 mg/L H_2O/min
UV Dosage, Reactor:	357 W/L H_2O/min

Pilot Plant Performance:

	Average Conc. (µg/l)	
	Influent	Effluent
Principal Contaminants in Ground Water		
methylene chloride	19	<5.0
1,1-dichloroethane	55	6
trichloroethylene	9	<5.0
1,1,1-trichloroethane	8	<5.0
benzene	12	<5.0
toluene	113	<5.0

Projected Operating & Maintenance Costs for 50,000 GPD* System - Assumes $0.08/KWH and replacement of UV lamps every 12 months:

	$/gal
Ozone Power Cost	0.0007
UV Power Cost	0.0022
Maintenance	0.0010
Monitoring Labor	0.0030
Total:	$0.0069

* Does not include equipment amortization

Projected Capital Equipment for 50,000 GPD System (Not Installed):

$150,000 (Add 15% for installation)

Table 3

Results of Radian (EPA) Demonstration and Projections for 2500 SCFM Air Pollution Catalytic System for a Stripping Tower

Test Operating Conditions:

Air Flow Rate: 16 ACFM

Ozone Dosage: 0.4 lb O_3/day

Operating Temperature: 90°F

Heater Power: 100W

Test Results:

	Average conc. (ppmv)	
Contaminants in Air	Influent	Effluent
Trichloroethylene (TCE)	2.9	less than 0.3
Dichloroethylene (DCE)	4.8	less than 0.3

GC/MS quantitative analysis of effluent air showed methyl formate and methyl acetate as only organic products.

Projected Additional Operating & Maintenance Costs for 2,500 SCFM Air Pollution Catalytic System (All Electric)*:

Assumes $0.075/KWH cost and an air/water ratio of 40.

	$/1000 gal
Heater Power (average)	0.095
Ozone Power Cost	0.05
Maintenance	0.02
Total:	$0.165

* Does not include equipment amortization. Projection based on testing - not optimized. Costs could be lower.

Projected capital equipment price for 2500 SCFM air pollution catalytic system for a stripping tower which treats 700,000 gallons per day of water contaminated with TCE and DCE** (uninstalled) is $115,000. Add 15% for installation.

** Based on test results - not optimized. Prices could be lower.